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PASSENGER FLOW ANALYSIS, 1978, RIVERSIDE LINE, MBTA

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16. Abstract

In order to complete a set of passenger flow estimates for use in a simulation model of a light rail line, a count of passenger movement was made at randomly selected stations in the underground section. Above-ground stations had been studied a year earlier. Eight surveyors were employed during one Monday through Friday period. The model which makes the data tractable is an analysis of variance model, with logarithmic transforms of the data. Although a satisfactory fit was obtained, discrepancies between the treatment of the 1977 and 1978 results made a validation necessary before the methods could be recommended for general use.

For planning purposes, information about the volume of ridership is essential. This study has shown that sufficiently accurate estimates can be gained without expending huge amounts of labor and money.

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PREFACE

The sample design and passenger flow estimation work described in this study was performed under Project Plan Agreement UM-937, sponsored by the Urban Mass Transportation Administration, Office of Planning Management and Demonstrations, Office of Transportation Management. The work was undertaken to develop a methodology of estimating the distribution of passenger flow for the Light Rail Transit at the underground stations. The techniques are developed in the context of the Massachusetts Bay Transit Authority - Riverside Line, but could be expanded to accommodate other transit properties with appropriate modifications. TSC Technical Program Manager is Mary Roos, DTS-722.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

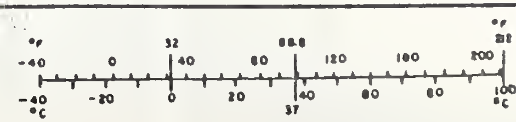


TABLE OF CONTENTS

Section		Page
I.	INTRODUCTION	1
II.	THE SURVEY PLAN	2
III.	DATA EDITING	8
IV.	SURVEY DATA ANALYSIS	12
V.	STATISTICAL MODEL TO PREDICT DATA GAPS	25
VI.	EVALUATION OF SURVEY RESULTS	48
VII.	CONCLUSION	51
	APPENDIX 1 - SURVEYOR DATA	1-1
	APPENDIX 2 - MBTA FILE STRUCTURE	2-1
	APPENDIX 3 - PROGRAM EXTRAC	3-1
	APPENDIX 4 - PROGRAMS EDIT AND EDIT1	4-1
	APPENDIX 5 - PROGRAMS EDIT2 AND EDIT3	5-1
	APPENDIX 6 - PROGRAM SEPAR	6-1
	APPENDIX 7 - FINAL OUTPUTS: PAKRIV AND PAKLEC	7-1
	APPENDIX 8 - PROGRAM PROPFL	8-1
	APPENDIX 9 - STATION PROFILE: PAKPFL	9-1
	APPENDIX 10 - PROGRAM CONTRAC	10-1
	APPENDIX 11 - PROGRAM COMBIN	11-1
	APPENDIX 12 - PROGRAM ESTRAG	12-1
	APPENDIX 13 - ANOVA RESULTS	13-1

LIST OF ILLUSTRATIONS

Figure		Page
1.	SCHEDULING OF THE PASSENGER SURVEY	5
2.	DISTRIBUTION OF LOADING PASSENGERS: CASE 1	17
3.	DISTRIBUTION OF UNLOADING PASSENGERS: CASE 1	18
4.	DISTRIBUTION OF LOADING PASSENGERS: CASE 2	20
5.	DISTRIBUTION OF UNLOADING PASSENGERS: CASE 2	21
6.	DISTRIBUTION OF LOADING PASSENGERS: CASE 3	23
7.	DISTRIBUTION OF UNLOADING PASSENGERS: CASE 3	24
8.	PLOT OF THE RESIDUALS, E_{IJ}, VS. THE PREDICTED VALUE, $\hat{R}_{IJ}$	34
9.	NORMALITY PLOT OF THE STANDARDIZED RESIDUALS (UNTRANSFORMED DATA)	36
10.	PLOT OF PREDICTED VALUES, $\hat{R}_{IJ}$, VS. THE ACTUAL, R_{IJ} (UNTRANSFORMED DATA)	37
11.	PLOT OF THE RESIDUALS, E_{IJ}, VS. THE PREDICTED VALUES, $\hat{R}_{IJ}$ (TRANSFORMED DATA)	45
12.	NORMALITY PLOT OF THE STANDARDIZED RESIDUALS, E_{IJ} (TRANSFORMED DATA)	46
13.	PLOT OF THE PREDICTED VALUES, $\hat{R}_{IJ}$, VS. THE ACTUAL, R_{IJ}	47
14.	PROFILE OF LOADING PASSENGERS AT PARK STREET STATION, 1978 (TO RIVERSIDE)	52

LIST OF TABLES

Table		Page
1.	SURVEY PLAN	7
2.	MBTA FILE STRUCTURE	9
3.	EDITING PROGRAMS	10
4.	OBSERVED PASSENGER LOADING RATES AT STATIONS (TRAINS TO RIVERSIDE)	13
5.	OBSERVED PASSENGER UNLOADING RATES AT STATIONS (TRAINS TO RIVERSIDE)	13
6.	OBSERVED PASSENGER LOADING RATES AT STATIONS (TRAINS TO NORTH STATION)	14
7.	OBSERVED PASSENGER UNLOADING RATES AT STATIONS (TRAINS TO NORTH STATION)	14
8.	ANOVA RESULTS ON RIVON.MTY: MODEL (2) ANALYSIS OF VARIANCE FOR THE REGRESSION (UNTRANSFORMED DATA)	32
9.	ANOVA RESULTS ON RIVON.MTY: MODEL (3) ANALYSIS OF VARIANCE FOR THE REGRESSION (TRANSFORMED DATA)	39
10.	ESTIMATED LOADING RATE (ALL RIVERSIDE TRAINS)	49
11.	ESTIMATED UNLOADING RATES (ALL RIVERSIDE TRAINS)	49
12.	ESTIMATED LOADING RATES (ALL NORTH STATION TRAINS)	50
13.	ESTIMATED UNLOADING RATES (ALL NORTH STATION TRAINS)	50

I. Introduction

This paper presents a sampling scheme and an estimation methodology to approximate passenger flows at a system of underground stations. The resulting data will be calibrated into a simulation model whose objective is to optimize the scheduling of the Light Rail Vehicle (LRV) to meet the daily changing passenger demands. Such an effort is part of an operation analysis system designed by the Transit Systems Branch, Urban Systems Division, Office of Ground Systems, to assist transit properties in their management of transit systems maintenance and operations.

When the LRV's were introduced in January of 1977 to Boston's Massachusetts Bay Transit Authority (MBTA) to gradually replace the old PCC's (President Conference Committee) on the Green Line, it was deemed necessary by the U.S. Department of Transportation, who funded 80% of the Boeing made cars, to identify areas of operational improvement and to conduct cost reduction studies. The project, sponsored by the Department's Urban Mass Transportation Administration, aims at employing simple analytical and data management tools to efficiently develop a prototype operations analysis system which can be modified and applied to various transit properties to fit their specific transit management needs.

Specifically, using MBTA's Riverside Line as the experimental unit, this study collects and analyzes passenger data at the thirteen underground stations. Thirteen daily profiles

of passenger loading and unloading rates are estimated so that the distribution of passenger flow at any given station at any time can be obtained. By varying the headways (and thus the schedules) of the trains, one can arrive at the optimal train schedule to accommodate the expected passenger demand.

II. The Survey Plan

A. Knowledge gained from the Survey at the Surface Stations

In May 1977, a sample of LRV trips to and from Riverside was selected and the loading and unloading passenger counts were taken by an onboard surveyor. This was done only for that part of the trip when the train remained on the surface and when the patrons of the LRV were allowed to board and alight through only one door. The underground stations pose a more complex problem. The amount of patronage increases several folds; all the trains are merged onto one track; and at least three doors are open as a train pulls in the station. A more efficient counting procedure is necessary, so that the distribution of passenger flow at these stations for the Riverside trains can be estimated with some degree of confidence without the investment of a large amount of resource and time.

Results of the analysis of 1977 surface station data have proved useful not only in the delineation of the sampling plan for the underground stations, but also in the verification of the resulted passenger profile thus obtained. First, one major finding in the analysis indicates an insignificant day to day difference in the total passenger volume using the LRV.

Second, it was also confirmed by statistical chi-square tests that each surface station holds in general a constant market share of the total passenger volume both for the morning and the afternoon hours. Hence it was possible, given a total trip passenger volume at any time, to ascertain an expected passenger volume from a certain station on the way. It is safe to deduce, therefore, that "station" (or location) and "time of day" are the two most important variables which determine potential passenger flows onto the LRV's. That is, we propose to investigate how the rate of passenger flow varies systematically with the two factors. The length of the headway, another essential parameter, will of course determine the actual congestion and the waiting time.

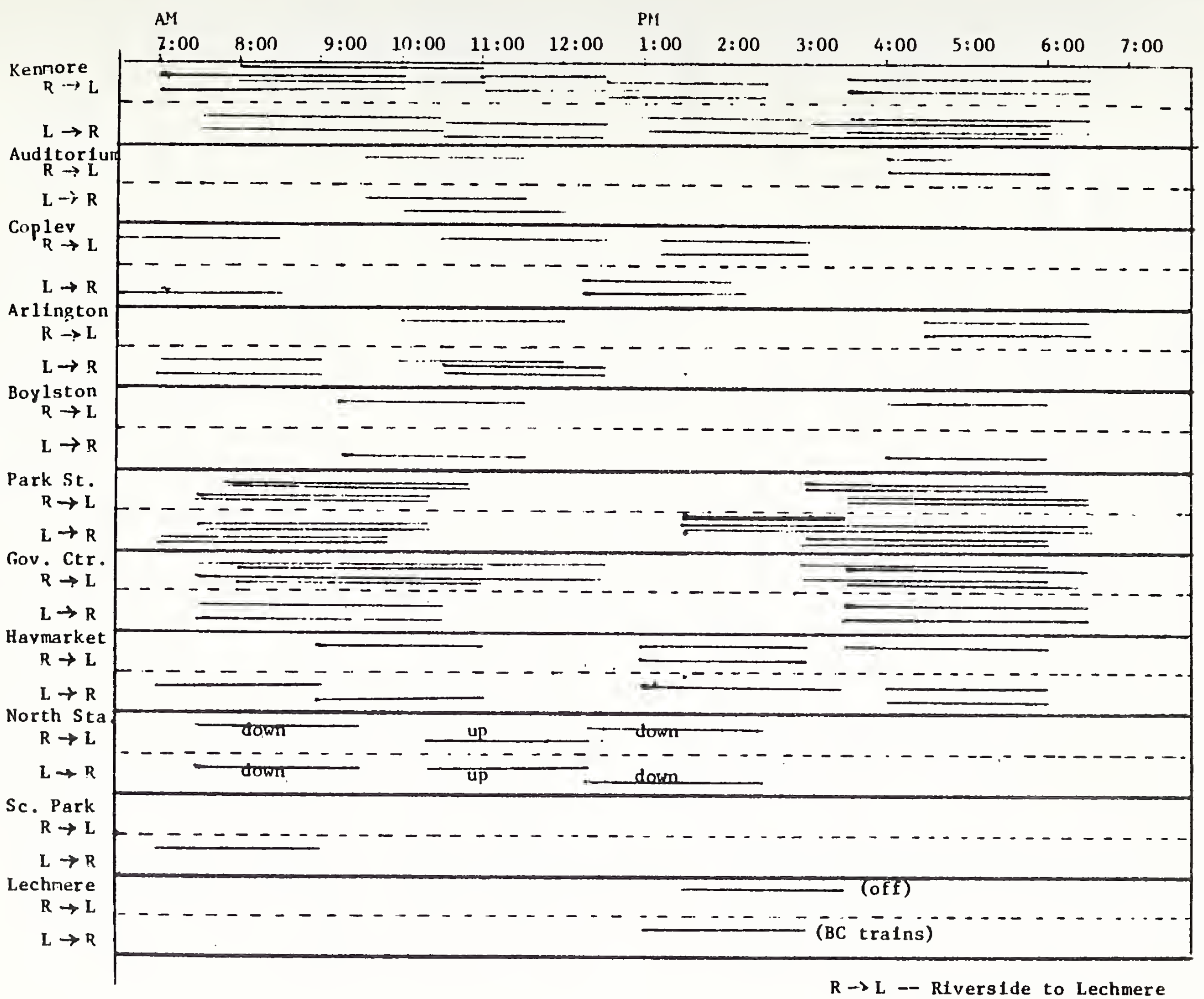
B. The Survey Plan at the Underground Stations

In May 1978, a new survey plan was devised whereby H. H. Aerospace, Inc., a minority contractor, would send a team of eight surveyors to the thirteen underground stations. Their mission: to collect passenger data on the Riverside trains, both inbound and outbound.

It is necessary to discuss the survey plan and field assignment in some detail because it is precisely the design of the survey that enables the analyst to draw meaningful inference from the survey data. The objective of the survey is to derive a representative daily distribution of passenger flows either by summarizing the survey data or by means of estimation using a simple statistical model. The use of a

statistical model economizes the number of observations required, because variation in the data is minimized by the control variables in the model. For example, indicator variables such as the location of the station and the time of the day probably explain much of the data variance, and a two factor analysis of variance (ANOVA) model seems most appropriate. The implementation of the model is the major criterion for the survey design.

Two other constraints are the time span (five days) in which the survey is to be conducted, and the labor resource (eight surveyors). The number of surveyors assigned to a station depends on the amount of passenger traffic the station receives. For example, four surveyors are assigned to Park Street Station at peak hours, while Auditorium or Boylston has been adequately manned by only one surveyor. Figure 1 displays a matrix of 110 cells, 40 of which are randomly selected and assigned to a team of surveyors (numbering from 1 to 4 depending on the needs of the station/shift.) There are two shifts for each station and each direction. Science Park and Lechmere, being the stations near or at the end of the line, have surveyors only at the outgoing (towards Riverside) direction. The random selection of the working shifts forms the primary sampling stage. The complexity of the plan arises when only eight people are sent to the field to work in these shifts. Here the objectivity of the survey design gives way to the subjective selection of the time span within each shift



R → L -- Riverside to Lechmere
L → R -- Lechmere (North Station) to Riverside

FIGURE 1. SCHEDULING OF THE PASSENGER SURVEY

based on a priori knowledge of the passenger flow at various stations and the desire to sample more heavily the busy stations and the peak hours. Each station is to be observed at one time or another and no time period is missed. The result is the survey plan delineated in Table 1, which gives Kenmore continual coverage as a point of reference to other stations.

The arrangement of labor resource, the suggestion of an optimal position from which the sampler can have a good view of the car doors, the layout of the station platform, and specific instructions during peak hours are all part of a two hour orientation/training for the samplers. Where it is difficult to count passengers at all doors (for example, during rush hours at busy stations) the samplers are to randomly select a car door for the count but systematically go to the next door of the second train when it comes around. This ensures the representativeness of the data when the counts are extrapolated to represent the entire train.

Appendix 1 is a sample of the data reported by a surveyor. Specifically, the data elements are the stations, the time of train arrival, the direction of the trip, the number of loading and unloading passengers at the car door, and the car characteristics. The samplers are also to report on other trains that pull in the station without trying to measure their loading and unloading activities, and note any unusual circumstances such as large group, train malfunction, etc.

TABLE 1. SURVEY PLAN

Station \ Day of Week		Monday	Tuesday	Wednesday	Thursday	Friday
Kenmore	AM		X			Ⓧ
	PM			X Ⓧ		X
Auditorium	AM		X Ⓧ			Ⓧ
	PM				X	
Copley	AM	X				
	PM	Ⓧ		X		
Arlington	AM			Ⓧ	X	
	PM	Ⓧ	X		Ⓧ	
Boylston	AM			X Ⓧ		
	PM	X Ⓧ				
Park St.	AM	Ⓧ		X		
	PM		X		Ⓧ	Ⓧ
Gov't Center	AM				X	Ⓧ
	PM	X				Ⓧ
Haymarket	AM	X	Ⓧ			
	PM	X	Ⓧ			X
North Station	AM			Ⓧ	X Ⓧ	
	PM		X			
Science Park	AM		Ⓧ			
	PM					
Lechmere	AM					
	PM		X		Ⓧ	

X Riverside to Lechmere (N.S.)

Ⓧ Lechmere to Riverside

To confirm the notion of nonsignificant daily variation of passenger demand, the survey design incorporates opportunities to retest that hypothesis. Samples are taken during the same time span for different days of the week at Auditorium, Arlington, and Park Street.

The design in effect offers the analyst an unreplicated discontinued time series of passenger flow for each station, unreplicated because no time periods (except those for hypothesis testing purposes) are repeated more than once, and discontinued in the sense that data gaps exist due to the labor constraint. It is the intention of Section IV, however, to attempt to fill these data gaps with an adequate statistical model and to estimate the daily trend of passenger demand with some degree of statistical confidence.

III. Data Editing

Like any other data collection activity, editing and data screening becomes an essential part of the total effort to prepare the data for analyses. Anomalies or obvious errors are to be corrected or discarded. If more than one surveyor is surveying the train, each being responsible for a car or a door, the results of each have to be combined. Or, if the combined passenger count still does not cover the entire train, extrapolation procedures are to be developed.

When the survey is completed, the data sheets are delivered to the keypunchers for the transcription of data into a file area in DEC-10. The file structure is outlined in Table 2.

TABLE 2. MBTA FILE STRUCTURE

Field Name	Field Description	Data Type	Length
MAYDAY	Survey date	Date	8
TIME	Time of train arrival	Integer	4
LINE	Line of train:	Text	2
	R=Riverside		
	CC=Cleveland Circle		
	BC=Boston College		
	H=Huntington/Arborway		
	K=Kenmore		
	N=North Station		
	L=Lechmere		
	GC=Government Center		
	P=Park Street		
TRAIN SIZE	Number of cars in the train	Integer	1
TYPE OF CAR	LRV=Light Rail Vehicle	Text	3
	PCC=President's Conference Committee		
PASSON	Number of loading passengers	Integer	3
PASSOFF	Number of unloading passengers	Integer	3

TABLE 2 (CONT.)

Field Name	Field Description	Data Type	Length
CAR1	X if car number 1 only or if the trainsize = 1, blank if otherwise	Text	1
CAR2	X if car number 2 is counted	Text	1
CAR3	X if car number 3 is counted	Text	1
DOOR1	X if door is counted, blank otherwise	Text	1
DOOR2	X if door 2 is counted, blank otherwise	Text	1
DOOR3	X if door 3 is counted, blank otherwise	Text	1
COLLECT	Surveyor's identifier from 1 to 4 since a maximum number of 4 workers can be assigned to a shift	Integer	1

In the file, each entry, representing one recording made by one surveyor has 13 fields. A series of editing programs delineated in Table 3 brings the file to its final form, with each entry representing one train observation at a station. (See Appendix 7.)

TABLE 3. EDITING PROGRAMS

Program Name	Function	Output File
EXTRAC (Appendix 3)	Extracts individual station data from the main MBTA file; sorts data by date and time, line, etc., so that the working area is reduced. It is here where data are screened manually for obvious errors.	station file such as "ARLINGTON" or "PARK ST"
EDIT (Appendix 4)	Uniquely identifies each car door whose passenger count is included in the surveyor's record.	STRA1 (working file)

TABLE 3. (CONT.)

Program Name	Function	Output File
EDIT2 (Appendix 5)	Takes STRA1 as input, combines passenger counts from each surveyor, extrapolating if necessary, to derive total train count*	STRA2.DMI (working file) to be made into a 1022 data file. (STRA2.DMS)
SEPAR (Appendix 6)	Separates STRA2.DMS into 2 files according to the direction of the train (inbound or outbound) and within each file sorts the data by time.	eg. PAKLEC and PAKRIV (final data, two files for each station) (Appendix 7)
PROFL (Appendix 8)	Takes PAKLEC or PAKRIV and computes headways, loading and unloading rate. Also counts the number of trains between Riverside trains.	eg. PAKPFL (Riverside) and PAKPFL.NOR (North Station) or PAKPFL.LEC (Lechemere). Each file represents an average daily passenger profile (raw data) at the station. (Appendix 9)
CONTRA (Appendix 10)	Takes ARLPFL or ARLPFL. NOR and computes loading and unloading rates for each half hour interval.	PAKCON.RIV or PAKCON.NOR (working files)
COMBIN (Appendix 11)	Combines all ***CON.RIV or ***CON.NOR files into two data matrices (one for loading passenger rates and one for unloading passenger rates) with "Stations" as the Columns and "time periods" as the Rows	RIVON.MTY RIVOFF. MTY or NORON. MTY NOROFF. MTY (Table 2)

*The extrapolating method is:

$$\text{TOTAL Train Count} = \frac{\text{total passengers count}}{\text{number of doors counted}} \times \text{total no. of doors on a train}$$

Assumes that passengers board trains equally at all doors which is not true for certain stations during certain time periods. Passengers tend to board door nearest turnstile entrance or stairwell.

The last two programs are necessary to prepare the data for input into a statistical model which synthesizes the information for all stations and all time periods to predict missing values, derives general trend for each station and estimates the average variation of passenger demand. Such a model is discussed in the next section. The matrices in Tables 4 through 7 show not only what is missing but give a bird's-eye-view of the sampling design.

IV. Survey Data Analysis

One of the assumptions underlying the sampling design is that one can pool the observations made at different days of the week to form a representative daily profile of an average week day. This assumption eliminates the necessity of obtaining sample data for each day of the week and deriving five daily profiles for each station. Previous analyses on the surface stations reflect little day to day difference in total passenger traffic. Our sampling design for the underground stations also allows for similar testing of the hypothesis. This section presents three cases in which two independent sets of passenger counts are obtained at a station during the same time span but for different days of the week. To each case, a nonparametric test, namely, the Mann-Whitney U test is applied to see if the distribution of the observations taken on Day 1 is different from those taken on Day 2.

TABLE 4. OBSERVED PASSENGER LOADING RATES AT STATIONS (TRAINS TO RIVERSIDE)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.	N. STA.	SCI. PK.	LECH.
700	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
730	0.00	0.00	0.73	0.00	0.00	3.22	0.00	2.24	0.00	0.00	0.00
800	1.00	0.00	0.82	3.11	0.00	8.53	1.35	4.87	11.68	0.30	0.00
830	0.19	0.00	1.14	2.39	0.00	13.41	5.75	2.06	13.19	0.28	0.00
900	0.53	0.00	0.00	0.84	0.00	6.33	2.81	5.22	3.90	0.21	0.00
930	0.10	0.00	0.00	0.78	0.00	4.18	4.73	0.00	4.80	0.16	0.00
1000	0.57	1.00	0.00	0.00	0.54	3.50	1.58	3.73	3.90	0.00	0.00
1030	0.36	0.38	0.00	1.15	0.60	4.57	1.71	2.22	0.00	0.00	0.00
1100	0.39	0.26	0.00	0.20	0.63	0.00	0.00	2.87	0.00	0.00	0.00
1130	0.48	0.52	0.00	0.47	1.11	0.00	0.00	0.00	0.00	0.00	0.00
1200	0.54	0.36	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1230	0.58	0.00	3.50	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1300	0.00	0.00	1.71	0.00	0.00	0.00	0.00	0.00	2.94	0.00	3.71
1330	1.05	0.00	1.57	0.00	0.00	0.00	0.00	0.00	1.00	0.00	3.58
1400	1.58	0.00	3.46	0.00	0.94	5.24	0.00	1.00	1.75	0.00	6.16
1430	0.69	0.00	2.00	0.00	0.77	4.55	0.00	1.93	2.77	0.00	3.47
1500	0.92	0.00	0.00	0.00	1.21	6.90	0.00	2.45	0.00	0.00	4.52
1530	0.83	0.00	0.00	0.00	0.00	12.33	0.00	1.69	0.00	0.00	5.70
1600	1.21	0.00	0.00	0.00	1.80	5.14	8.57	3.84	0.00	0.00	0.00
1630	1.06	0.00	0.00	0.00	1.28	7.11	6.25	1.65	0.00	0.00	0.00
1700	2.15	0.00	0.00	0.00	2.10	15.56	9.18	2.15	0.00	0.00	0.00
1730	2.96	0.00	0.00	0.00	1.52	15.23	12.87	0.00	0.00	0.00	0.00
1800	1.65	0.00	0.00	0.00	1.50	9.23	7.17	5.55	0.00	0.00	0.00
1830	0.81	0.00	0.00	0.00	0.00	10.80	5.63	0.00	0.00	0.00	0.00
1900	0.00	0.00	0.00	0.00	0.00	0.00	4.36	0.00	0.00	0.00	0.00
1930	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 5. OBSERVED PASSENGER UNLOADING RATES AT STATIONS (TRAINS TO RIVERSIDE)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.
700	0.00	0.00	4.57	0.00	0.00	0.00	0.00	0.00
730	0.00	0.00	3.16	0.00	0.00	1.22	0.00	0.04
800	3.00	0.00	6.68	8.20	0.00	1.97	1.00	0.09
830	4.19	0.00	8.19	7.91	0.00	4.74	1.96	0.06
900	5.05	0.00	0.00	4.26	0.00	3.20	0.57	0.13
930	1.79	0.00	0.00	2.17	0.00	1.76	0.44	0.00
1000	1.33	4.33	0.00	0.00	0.81	3.25	0.81	0.00
1030	1.44	0.66	0.00	2.65	1.65	1.10	0.43	0.00
1100	1.78	0.35	0.00	0.55	0.20	0.00	0.00	0.00
1130	1.55	0.71	0.00	0.80	0.89	0.00	0.00	0.00
1200	1.68	0.73	0.00	2.63	0.00	0.00	0.00	0.00
1230	0.48	0.00	6.00	1.35	0.00	0.00	0.00	0.00
1300	0.00	0.00	3.03	0.00	0.00	0.00	0.00	0.00
1330	1.77	0.00	2.80	0.00	0.00	0.00	0.00	0.00
1400	2.32	0.00	3.15	0.00	0.44	3.48	0.00	0.24
1430	6.42	0.00	2.20	0.00	0.18	2.28	0.00	0.07
1500	3.81	0.00	0.00	0.00	0.34	1.87	0.00	0.03
1530	1.87	0.00	0.00	0.00	0.20	7.00	0.00	0.38
1600	2.66	0.00	0.00	0.00	2.60	3.38	0.57	0.00
1630	3.38	0.00	0.00	0.00	1.09	4.31	1.82	0.00
1700	7.38	0.00	0.00	0.00	1.34	8.76	1.05	0.04
1730	10.04	0.00	0.00	0.00	0.18	5.37	0.87	0.00
1800	8.06	0.00	0.00	0.00	0.94	4.00	0.63	0.50
1830	2.75	0.00	0.00	0.00	0.00	5.70	0.44	0.00
1900	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
1930	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 6. OBSERVED PASSENGER LOADING RATES AT STATIONS (TRAINS TO NORTH STATION)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.
700	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00
730	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00
800	0.00	0.00	1.75	0.00	0.00	8.10	0.14	0.00
830	3.06	0.00	3.36	1.84	0.00	2.28	0.13	0.00
900	5.81	0.00	0.00	2.17	0.00	0.63	0.43	0.00
930	1.14	0.00	0.00	0.42	0.00	0.79	0.54	0.13
1000	0.35	0.96	0.00	0.00	0.33	1.21	0.15	0.00
1030	1.14	1.66	0.00	0.92	0.07	1.00	0.33	0.06
1100	3.29	1.13	0.94	1.00	0.16	0.81	0.94	0.00
1130	0.93	1.45	1.26	0.36	0.62	0.00	0.11	0.00
1200	1.75	0.00	0.46	0.56	0.00	0.00	0.10	0.00
1230	1.66	0.00	5.23	0.00	0.00	0.00	0.03	0.00
1300	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1330	2.94	0.00	1.60	0.00	0.00	0.00	0.00	0.07
1400	3.84	0.00	2.38	0.00	0.00	0.00	0.00	0.04
1430	3.96	0.00	1.74	0.00	0.00	0.00	0.00	0.05
1500	0.00	0.00	3.11	0.00	0.00	0.00	0.00	0.00
1530	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00
1600	2.00	0.00	0.00	0.00	0.00	1.80	1.30	0.00
1630	3.67	2.54	0.00	0.00	0.63	5.81	0.24	0.58
1700	2.14	1.36	0.00	1.58	1.09	2.18	0.90	2.22
1730	4.35	4.90	0.00	3.90	0.53	5.70	0.97	0.24
1800	1.08	1.42	0.00	2.50	0.08	1.00	0.72	0.00
1830	0.83	0.00	0.00	1.19	0.25	1.11	0.26	0.00
1900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1930	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 7. OBSERVED PASSENGER UNLOADING RATES AT STATIONS (TRAINS TO NORTH STATION)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.	N. STA.
700	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00
730	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00
800	0.00	0.00	2.69	0.00	0.00	22.07	20.43	0.00	5.15
830	0.50	0.00	3.96	3.90	0.00	10.69	11.65	0.00	1.09
900	0.38	0.00	0.00	4.67	0.00	13.07	16.97	0.00	3.53
930	0.59	0.00	0.00	2.96	0.00	5.56	7.15	0.47	1.09
1000	0.35	2.67	0.00	0.00	0.89	8.66	6.88	0.94	0.00
1030	0.47	1.45	0.00	1.46	0.52	5.11	2.93	2.22	0.00
1100	0.43	1.45	1.44	1.57	0.61	7.19	3.97	0.49	0.00
1130	0.00	0.68	0.85	0.62	1.12	0.00	1.14	0.00	0.00
1200	0.32	0.00	1.19	0.96	0.00	0.00	5.10	0.00	0.00
1230	0.88	0.00	1.15	0.00	0.00	0.00	4.92	0.00	0.00
1300	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.56
1330	0.50	0.00	0.68	0.00	0.00	0.00	0.00	0.50	2.14
1400	1.09	0.00	2.00	0.00	0.00	0.00	0.00	2.39	1.82
1430	1.04	0.00	0.72	0.00	0.00	0.00	0.00	2.26	2.36
1500	0.00	0.00	0.86	0.00	0.00	0.00	0.00	3.69	0.00
1530	0.00	0.00	0.00	0.00	0.00	10.33	0.00	0.00	0.00
1600	0.29	0.00	0.00	0.00	0.00	8.17	5.52	0.00	0.00
1630	0.39	0.85	0.00	0.00	0.38	16.22	4.79	3.96	0.00
1700	0.23	0.71	0.00	0.50	0.74	10.30	4.67	9.04	0.00
1730	0.39	0.90	0.00	0.94	0.41	12.33	5.34	9.05	0.00
1800	0.50	0.77	0.00	0.88	0.46	7.76	3.62	3.41	0.00
1830	1.37	0.00	0.00	0.85	0.25	3.66	2.39	0.00	0.00
1900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1930	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The method requires the assignment of rank w_i to each of the $n_1 + n_2$ observations according to its magnitude, where n_1 and n_2 are the total numbers of observations for Day 1 and Day 2 respectively. A U statistic is then formed by

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - \sum_{i \in \text{Day } 1} W_i$$

$$U' = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - \sum_{i \in \text{Day } 2} W_i$$

A two tailed test for the hypothesis, H, that the two samples come from the same population and thus have the same distribution is as follows:

At a significance level $\alpha = .05$, H_o is rejected if

$\min (U,U') \leq C_{(\alpha/2,\ n_1,n_2)}$ or

$\min (U,U') > C_{(1-\alpha/2,n_1,n_2)}$

where $C_{(\alpha/2,\ n_1,n_2)}$ is obtained from the table of critical values of U in the Mann-Whitney Test (Appendix14) and

$C_{(1-\alpha/2,n_1 n_2)} = n_1 n_2 - C_{(\alpha/2,n_1,n_2)}$.

In all of the three cases in the following, the test confirms the assumption of insignificant day to day variation in the average passenger flow for the underground

stations. Along with each test result, the actual data is plotted graphically to reflect the similarity of their distributions.

Case 1: Park Street Station, 1:30pm - 3:30 pm (Figures 2 and 3).

Loading Passengers

$$U = 16 \times 16 + \frac{16(16 + 1)}{2} - 224$$

$$= 168$$

$$U' = 16 \times 16 - 224 = 88$$

$$\min (U,U') = 88$$

$$C_{\alpha/2} = 75$$

$$C_{1-\alpha/2} = 181$$

Hence $C_{\alpha/2} \leq \min(U,U') < C_{1-\alpha/2}$ and H_o is accepted.

Unloading Passengers

$$U = 16 \times 16 + \frac{16(16 + 1)}{2} - 279.50 = 112.50$$

$$U' = 16 \times 16 - 112.50 = 143.50$$

$$\min (U,U') = 112.50$$

$$C_{(\alpha/2,n_1,n_2)} = 75$$

$$C_{(1-\alpha/2,n_1,n_2)} = 181$$

Hence $C_{(1/2,n_1,n_2)} \leq \min (U,U') < C_{(1-\alpha/2,n_1,n_2)}$

and H_o is accepted.

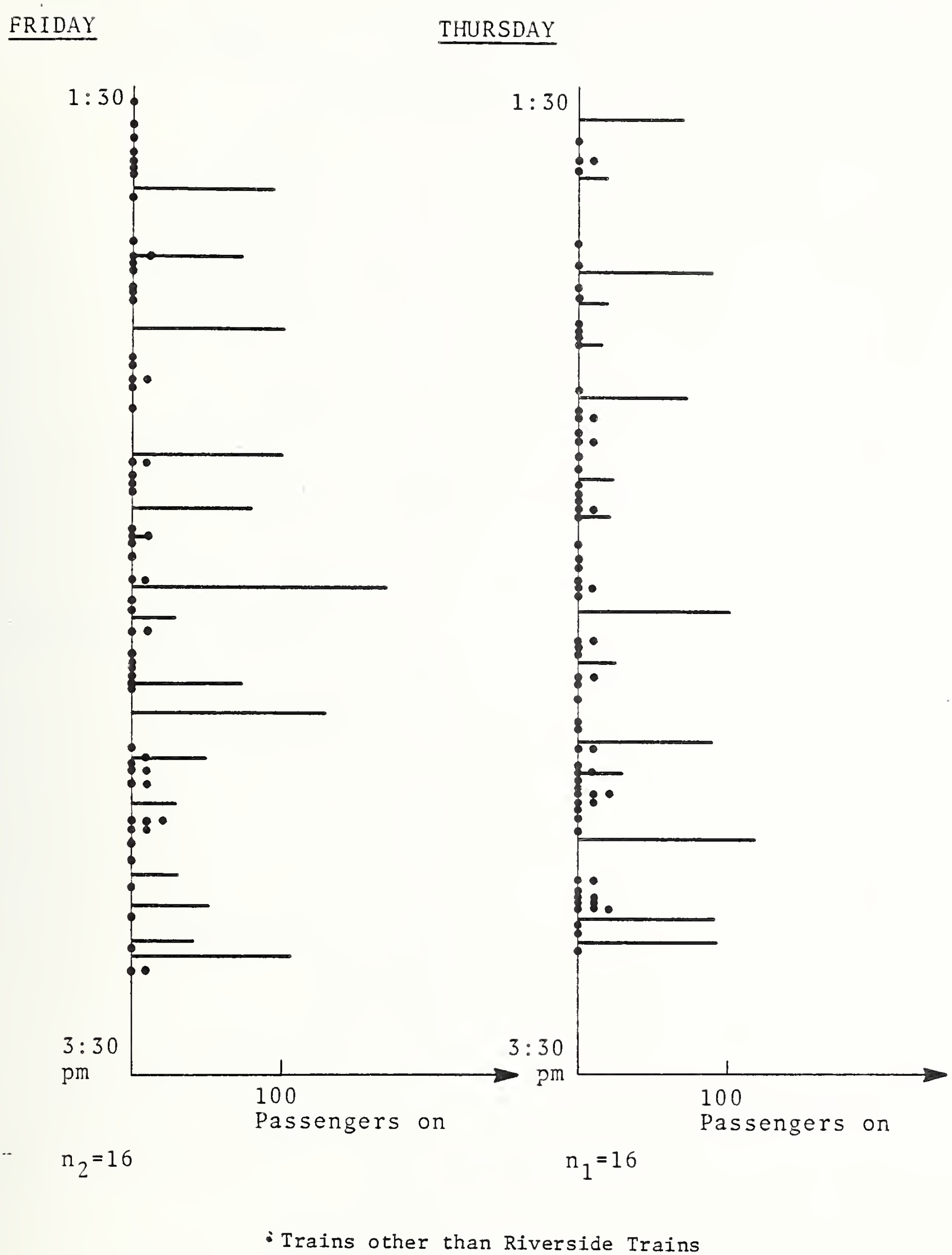


FIGURE 2. DISTRIBUTION OF LOADING PASSENGERS: CASE 1

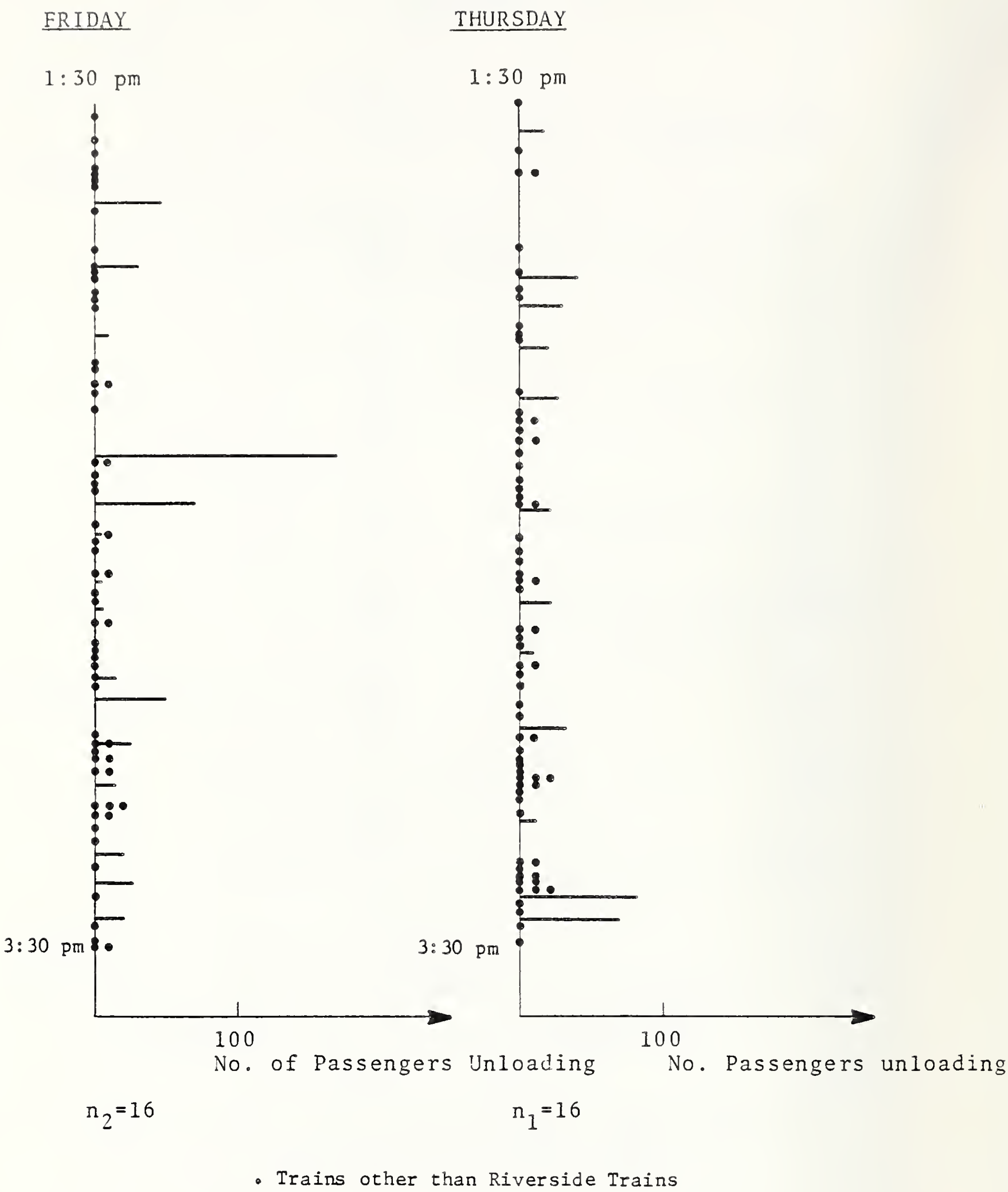


FIGURE 3. DISTRIBUTION OF UNLOADING PASSENGERS: CASE 1

Case 2: Auditorium Station, 10:00 am - 12:00 pm (Figures 4 and 5).

Loading Passengers

$$U = 10 \times 13 + \frac{10(10 + 1)}{2} - 116.5$$

$$= 68.50$$

$$U' = 61.50$$

$$\min (U,U') = 61.50$$

$$C_{(\alpha/2,n_1,n_2)} = 33$$

$$C_{(1-\alpha/2,n_1,n_2)} = 97$$

Hence $C_{(\alpha/2,n_1,n_2)} \leq \min (U,U') < C_{(1-\alpha/2,n_1,n_2)}$

and H_o is accepted.

Unloading Passengers

$$U = 10 \times 13 + \frac{10(10 + 1)}{2} - 118$$

$$= 67$$

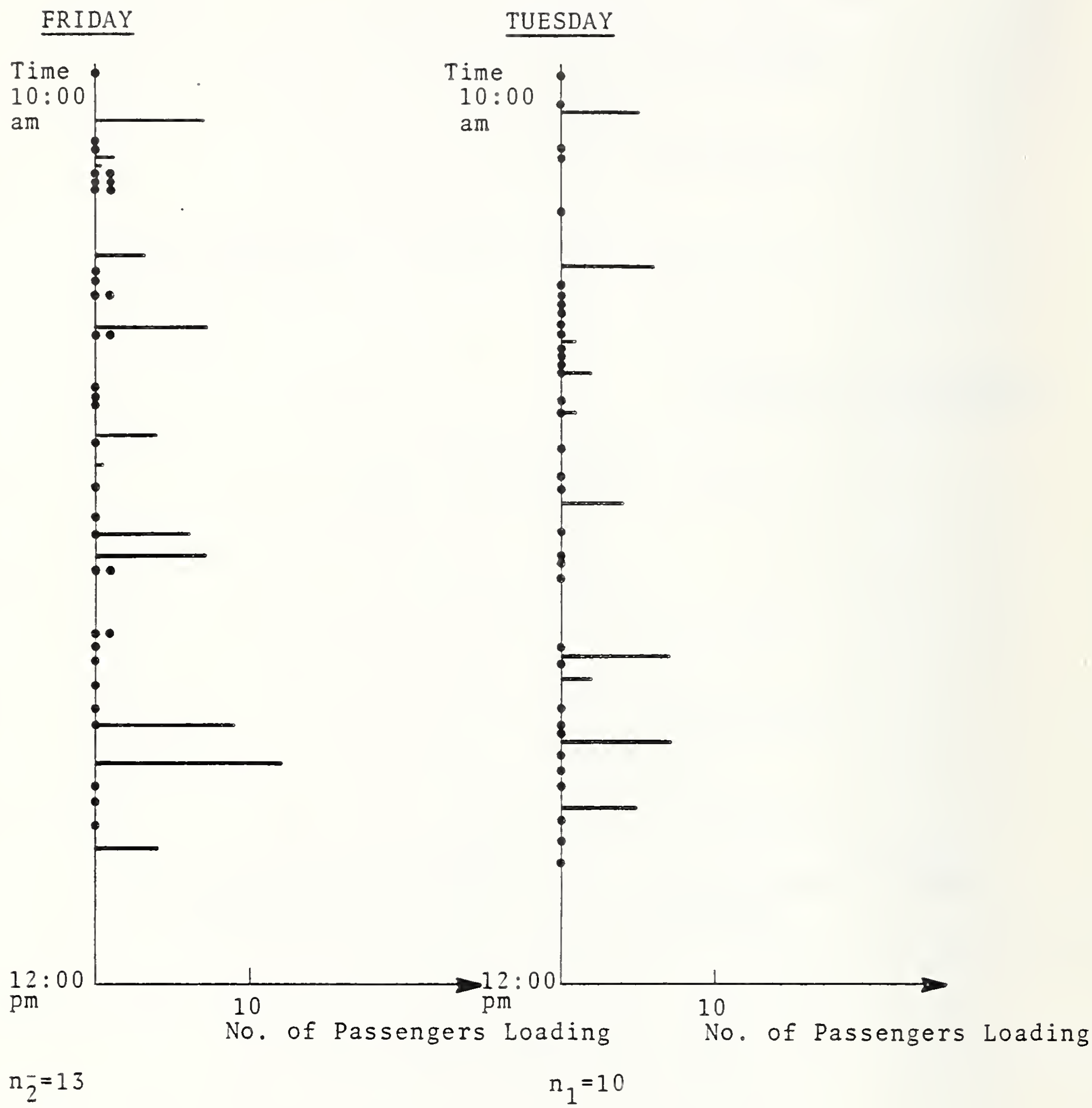
$$U' = 63$$

$$\min (U,U') = 63$$

$$C_{(\alpha/2,n_1,n_2)} = 33$$

$$C_{(1-\alpha/2,n_1,n_2)} = 97$$

Hence $C_{(1-\alpha,n_1,n_2)} \leq \min (U,U') < C_{(1-\alpha/2,n_1,n_2)}$



• Trains other than Riverside Trains

FIGURE 4. DISTRIBUTION OF LOADING PASSENGERS: CASE 2

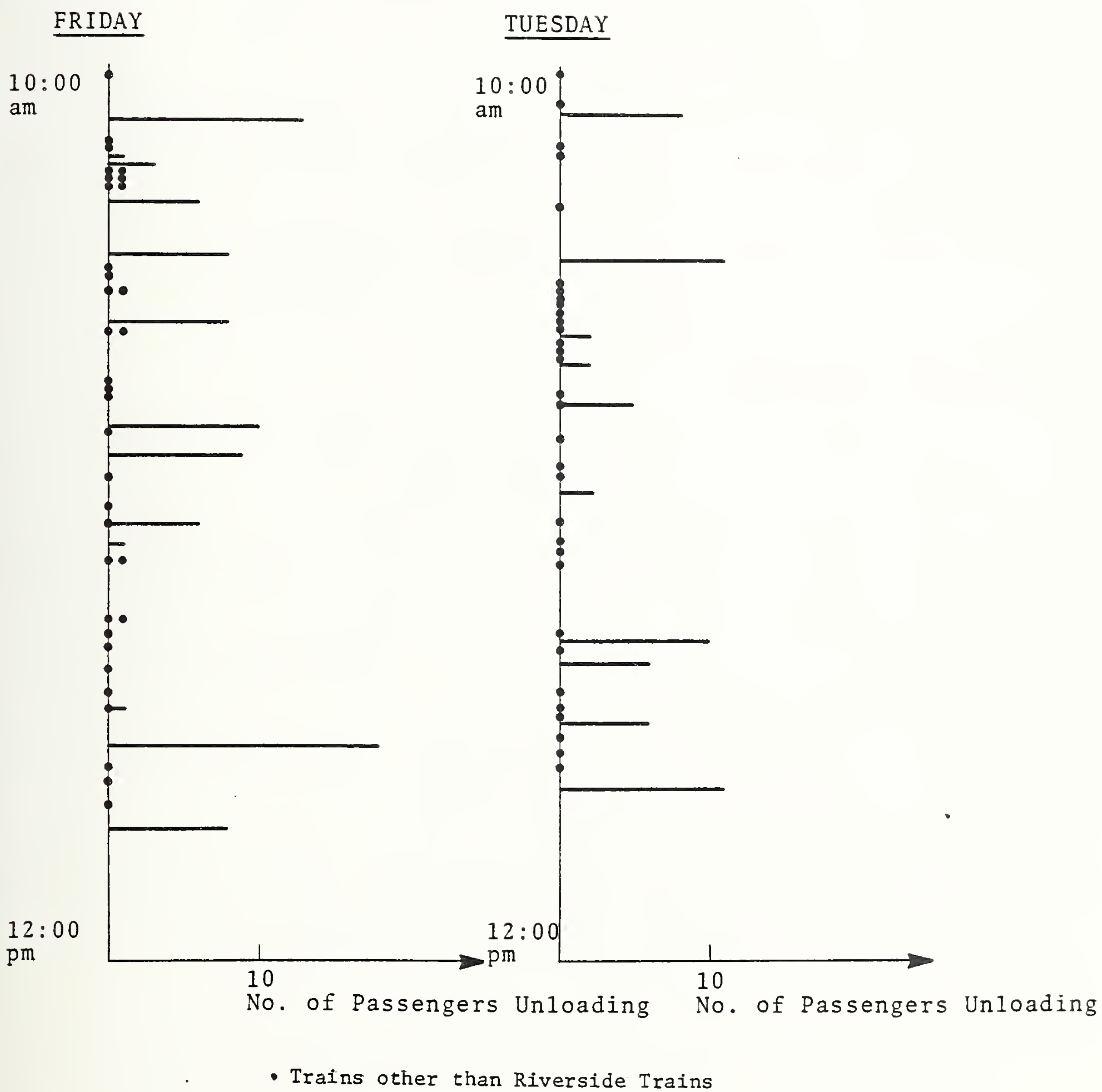


FIGURE 5. DISTRIBUTION OF UNLOADING PASSENGERS: CASE 2

Case 3: Arlington Station, 10:00 am - 12:00 pm (Figures 6 and 7)

$$U = 8 \times 11 + \frac{8(8+1)}{2} - 74$$

$$= 50$$

$$U' = 8 \times 11 - 50 = 38$$

$$\min(U,U') = 38$$

$$C_{(\alpha/2,n_1,n_2)} \doteq 19$$

$$C_{(1-\alpha/2,n_1,n_2)} = 69$$

Hence $C_{(\alpha/2,n_1,n_2)} \leq \min(U,U') < C_{(1-\alpha/2,n_1,n_2)}$

and H_o is accepted.

Unloading Passengers

$$U = 8 \times 11 + \frac{8(8+1)}{2} - 89$$

$$= 35$$

$$U' = 8 \times 11 - 35 = 53$$

$$\min(U,U') = 35$$

$$C_{(\alpha/2,n_1,n_2)} = 19$$

$$C_{(1-\alpha/2,n_1,n_2)} = 69$$

Hence $C_{(\alpha/2,n_1,n_2)} < \min(U,U') < C_{(1-\alpha/2,n_1,n_2)}$

and H_o is accepted.

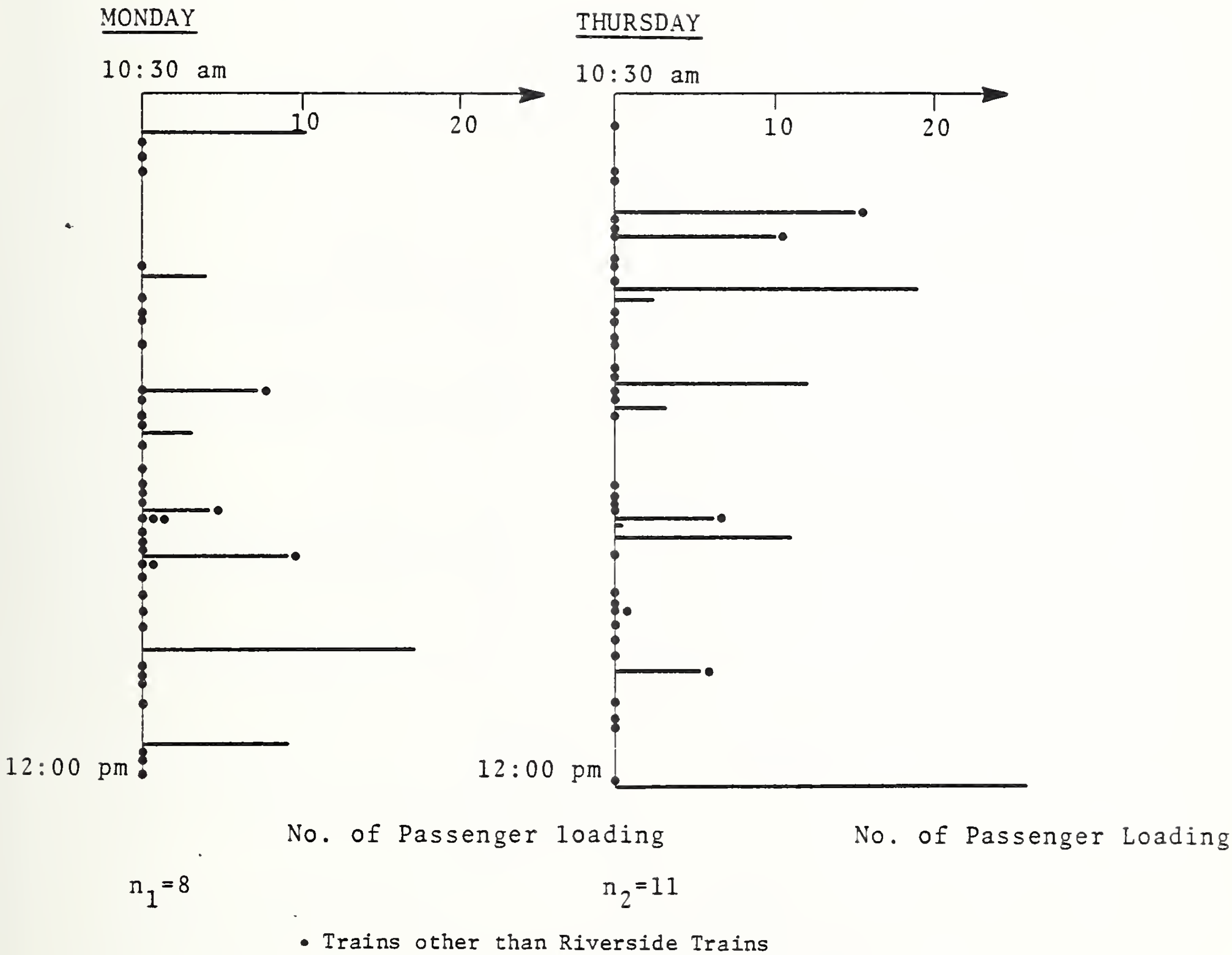


FIGURE 6. DISTRIBUTION OF LOADING PASSENGERS: CASE 3

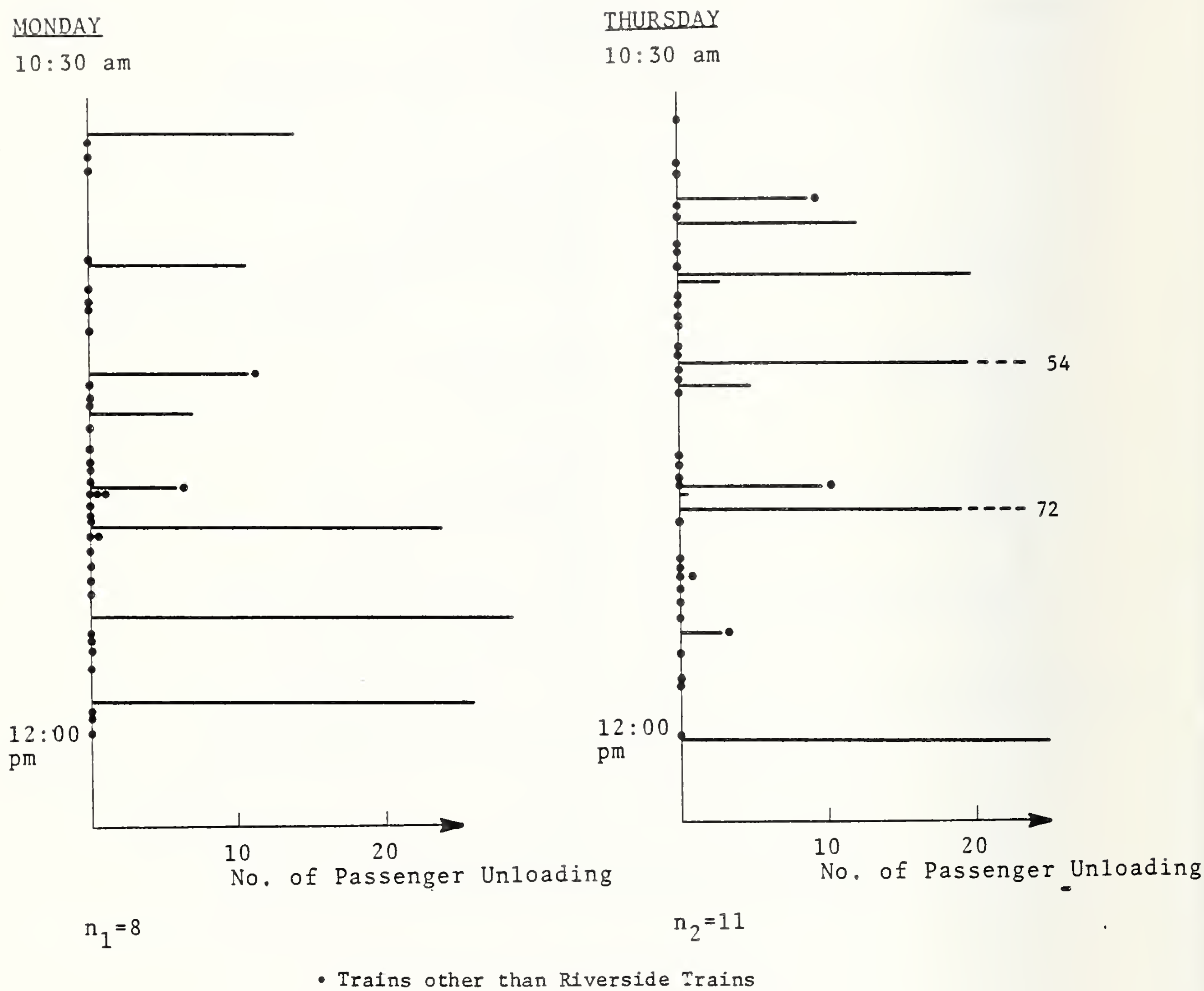


FIGURE 7. DISTRIBUTION OF UNLOADING PASSENGERS: CASE 3

V. Statistical Model to Predict Data Gaps

A. Background

Tables 4 through 7 show four two dimensional matrices with "station" as columns and "time period" as rows. The half hourly periods are used for two reasons. First, a uniform time scale is required for all stations if all the information is pooled together in the statistical model such that a prediction of passenger demand at Park Street, for example, will depend on the knowledge of passenger demand for the same time span at other stations. Secondly, because of the variable headways of the train arrival, a thirty-minute interval is the smallest time interval for which a meaningful estimate of average passenger arrival rate can be obtained. Cutting the interval into anything smaller would introduce too many data gaps.

Hence Tables 4 through 7 in fact present four matrices containing the average passenger rate of flow for each time period and each station, on each of which a two-factor analysis of variance can be performed, a technique that investigates the simultaneous effects of two factors, namely "station" and "time" on the response cell, the passenger loading and unloading rate. That is, if we designate R_{IJ} be the average passenger rate for station J and time period I, R_{IJ} can be expressed as a sum of five components:

$$R_{IJK} = \mu + \alpha_I + \beta + (\alpha\beta)_{IJ} + \varepsilon_{IJK} \qquad (1)$$

where μ is the grand mean, α_I, the effect contributed by time period I, β_J the effect contributed by station J, $(\alpha\beta)_{IJ}$ the effect contributed by the interaction between station I and time J, and ε_{IJK} the random error term.

Certain constraints are placed on Model (1). They are:

$$\sum_I \alpha_I = 0, \quad \sum_J \beta_J = 0, \quad \sum_I (\alpha\beta)_{IJ} = 0, \quad \sum_J (\alpha\beta)_{IJ} = 0$$

ε_{IJK}'s are uncorrelated with mean zero and variance σ^2.

This model is generally called a "fixed effect" two-way ANOVA since the factor levels I and J are of intrinsic interest themselves. If all the constraints are satisfied, R_{IJK} are then independently distributed as $N(\mu + \alpha_I + \beta_J + (\alpha\beta)_{IJ}, \sigma^2)$.

B. Modification of Model (1)

Model (1) will be modified as follows:

- o assumption of unimportant interaction effects, or, for all I,J pairs, $(\alpha\beta)_{IJ} = 0$
- o application of a generalized linear model because of missing data or empty cells.

Table application of a straightforward two-way ANOVA to the matrices in Tables 4 through 7 seems simple enough. However, there is at most only one observation per cell (i.e. K = 1), not to mention the empty cells for which data is lacking and the prediction of which is precisely the objective this model set out to fulfill. Having one observation per cell

implies the infeasibility of estimating the error term without assuming the interaction effect $(\alpha B)_{IJ}$ be zero or insignificant. Empty cells make it inappropriate to use any standard ANOVA statistical computer package which usually requires balanced data (i.e. equal sample size per cell). Setting $(\alpha\beta)_{IJ} = 0$, Model (1) then becomes:

$$R_{IJ} = \mu + \alpha_I + \beta_J + \varepsilon_{IJ} \tag{1.a}$$

a) Regression Approach to the Analysis of Variance Problem

When the cells of the ANOVA matrix have unequal sample sizes or empty cells, the regular ANOVA equations are no longer of a simple structure. The best alternative is to re-express the ANOVA model by its regression model counterpart. In formulating the regression model, we use indicator variables to represent the "station" effects and the "time" effects. Specifically we have:

$$R_{IJ} = \mu + \sum_i a_i T_i + \sum_j b_i S_j + \varepsilon_{IJ} \tag{2}$$

where T_i and S_j are defined as:

$$\begin{aligned} T_i &= 1 && \text{if } i = I \text{ and } I \neq t \\ &= -1 && \text{for all } i \text{ if } I = t \\ &= 0 && \text{otherwise} \end{aligned}$$

$$S_j = 1 \quad \text{if } j = J \text{ and } J \neq s$$
$$= -1 \quad \text{for all } j \text{ if } J = s$$
$$= 0 \quad \text{otherwise}$$

for all $i = 1,2,3,\ldots t-1$, t being the number of time periods

and $j = 1,2,3,\ldots s-1$, s being the number of stations

μ, a_i, b_j are parameters to be estimated, and ε_{IJ} the usual random error term; ε_{IJ} are uncorrelated with mean $E(\varepsilon_{IJ}) = 0$ and variance $v(\varepsilon_{IJ}) = \sigma^2$.

We note that the regression approach (Model (2)) gives rise to the same result as the ANOVA Model (1.a). The indicator variables are coded in such a way that their regression coefficients correspond directly to the level effects in Model (1.a). To illustrate, for a particular I,J pair, $I \neq t$ and $J \neq s$,

Model (1.a) gives: $R_{IJ} = \mu + \alpha_I + \beta_J + \varepsilon_{IJ}$

Model (2) gives: $R_{IJ} = u + a_I + b_J + \varepsilon_{IJ}$.

For $I = t$ and $J = s$,

Model (1.a) gives: $R_{ts} = \mu + \alpha_t + \beta_s + \varepsilon_{ts}$

Model (2) gives: $R_{ts} = u - \sum_i a_i - \sum_j b_j + \varepsilon_{ts}$

$i = 1,\ldots t-1$ and

$j = 1,\ldots s-1$.

If one equates R_{IJ} of Model (1.a) to that of Model (2), the set of simultaneous equations will result in the following identities:

$$\mu = u$$

$$\alpha_I = a_I \qquad \text{for all } I \neq t$$

$$\alpha_t = - \sum_i a_i = a_t \quad i = 1, \ldots t-1$$

$$\beta_J = b_J \qquad \text{for all } J \neq s$$

$$\beta_s = - \sum_j b_j = b_s \quad j = 1, \ldots s-1$$

Still the regression approach assumes the interaction effect is insignificant because the addition of interaction variable, $(TS)_{ij}$, for all possible i,j pairs, makes the equation cumbersome. Moreover, the number of observations available may not support the estimation of the vast number of parameters (or regression coefficients). From the analysis on surface station data, we are shown that each surface station has a constant market share of passenger demand during each time period. For the underground stations, however, many of which are transfer points such as Park Street, Government Center, Haymarket, and North Station, additional evidence about the assumption is necessary.

b) Tukey One Degree of Freedom Test for Interaction

Tukey postulated that, in an ANOVA model, if $(\alpha\beta)_{IJ}$ is any second degree polynomial function of α_I and β_J, then the interaction term would be in the form:

$$(\alpha\beta)_{IJ} = D\alpha_I\beta_J$$

for some constant D, to satisfy the constraints set forth under Model (1). The interaction sum of squares, SSAB, will be:

$$SSAB = \sum_I \sum_J (\alpha\beta)^2_{IJ} = \sum_I \sum_J D^2\alpha^2_I\beta^2_J$$

Assuming α_I, β_J are known, the least square estimator of D is:

$$D = \frac{\sum_I \sum_J \alpha_I\beta_J R_{IJ}}{\sum_I \alpha^2_I \sum_J \beta^2_J} \qquad I = 1,\ldots t,\ J=1,\ldots s.$$

The test statistic for interaction, FSTAT, when only one observation per cell is available, is then a function of the approximate sum of squares for interaction (SSAB) and the sum of squares of error (SSE).

$$FSTAT = \frac{SSAB}{1} \Big/ \frac{(SSE - SSAB)}{(df\ for\ SSE - 1)}$$

It is important in our estimation of the distribution of the passenger demand to assure the correctness of all the assumptions we have set forth in the beginning. Our hypothesis is:

H_0 = Constant market shares for underground stations, no interaction between "station" and "time".

H_1 = Interaction exists. A particular station at a particular time may have unusually heavy or light traffic than what other stations normally call for.

The test statistic FSTAT is distributed F(1, df(SSE)-1), and large values of FSTAT would lead to conclusion H_1.

C. Presentation of Results

It is intended in this section to dwell on the regression results of the input matrix from Table 4 in detail and briefly discuss the others since similar analyses are performed on each of them. Table 8 presents the regression results on RIVON.MTY. There are t = 25 time periods and s = 11 stations, making the number of parameters (25-1) + (11-1) = 34 plus an intercept term. The total number of observations (loading passenger rate) is n=120.

An examination of Table 8 reveals the following facts about the aptness of the Model (2) when applied to this set of data:

- The regression shows an F value of 6.78 which, when compared to an f(24.85) at a signficance level of α = .05, is highly significant. The multiple

TABLE 8. ANOVA RESULTS ON RIVON.MTY: MODEL (2) ANALYSIS OF VARIANCE FOR THE REGRESSION (UNTRANSFORMED DATA)

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F-VALUE
ATTRIBUTABLE TO REGRESSION	34.	1028.2714	30.2433	6.7834
DEVIATION FROM REGRESSION	85.	378.9656	4.4584	

INTERCEPT= 2.975
MULTIPLE CORR. COEFF.=.85481 $R^2 = .73$
STANDARD ERROR OF ESTIMATE= 2.111

VARIABLE	REGR. COEFF.	STD.ERROR, OF COEFF.	COMPUTED T-VALUE
2	-1.9401	2.1768	-0.8913
3	-2.2433	1.2277	-1.8273
4	0.7824	0.7692	1.0173
5	1.6262	0.7692	2.1143
6	-0.4358	0.8249	-0.5283
7	-0.8862	0.8929	-0.9925
8	-1.2497	0.8169	-1.5298
9	-1.1731	0.8204	-1.4300
10	-0.4986	0.9767	-0.5105
11	-0.3600	1.0977	-0.3279
12	-0.3913	1.2728	-0.3074
13	0.2282	1.2353	0.1847
14	-1.7326	1.2827	-1.3508
15	-1.7481	1.0932	-1.5991
16	-0.7497	0.8170	-0.9177
17	-1.3140	0.8170	-1.6084
18	-0.2261	0.9615	-0.2352
19	1.0489	1.0724	0.9781
20	0.7936	0.9520	0.8336
21	0.1516	0.9520	0.1592
22	2.9096	0.9520	3.0563
23	4.7028	1.0614	4.4305
24	1.7016	0.9520	1.7874
25	1.4157	1.2179	1.1624
26	-2.3406	0.4822	-4.8540
27	-1.7365	0.9928	-1.7491
28	-0.4649	0.7845	-0.5926
29	-1.6041	0.7266	-2.2078
30	-2.1990	0.6375	-3.4492
31	4.6118	0.5378	8.5759
32	1.7968	0.6360	2.8252
33	-0.1519	0.5641	-0.2693
34	2.7625	0.7123	3.8784
35	-3.0092	1.0478	-2.8718

THE INTERACTION TEST STAT. , FSTAT: 78.1136

ORIG.RATE	FITTED RATE	RESIDUAL	STAND.RES.
0.00	-1.31	1.31	0.62
0.00	-0.70	0.70	0.33
0.57	0.57	0.00	0.00
0.00	-0.57	0.57	0.27

correlation coefficient R^2 = .73 indicates that the regression has explained about 73% of the variation in the passenger data.

- Small t values are attached to some of the regression coefficients showing some stations or time periods have similar mean levels of passenger traffic. The usual approach of eliminating an insignificant variable does not apply when the objective is not determining the correlation between variables, but rather the estimation of level means.
- The FSTAT statistic for testing interaction between the station factor and the time factor is disturbingly large (FSAT = 78.11). At any significance level, it is concluded that our assumption of $(\alpha\beta)_{IJ} = 0$ in Model (1.a) is not justified. To remove the existing interaction, a transformation of the data may prove useful.

By examining the residuals, ε_{IJ}, additional information can be obtained and the aptness of the model determined.

- Figure 8 shows a plot of the residuals, ε_{IJ}, vs. the fitted values, $\hat{R}_{IJ}$. It reveals a gradual increase in the variation of the residuals around the expected mean $E(\varepsilon_{IJ}) = 0$. As the value of $\hat{R}_{IJ}$ increases, so also does the deviation from the mean. Heteroschedasity, or unequal variance in the residuals, is apparent.

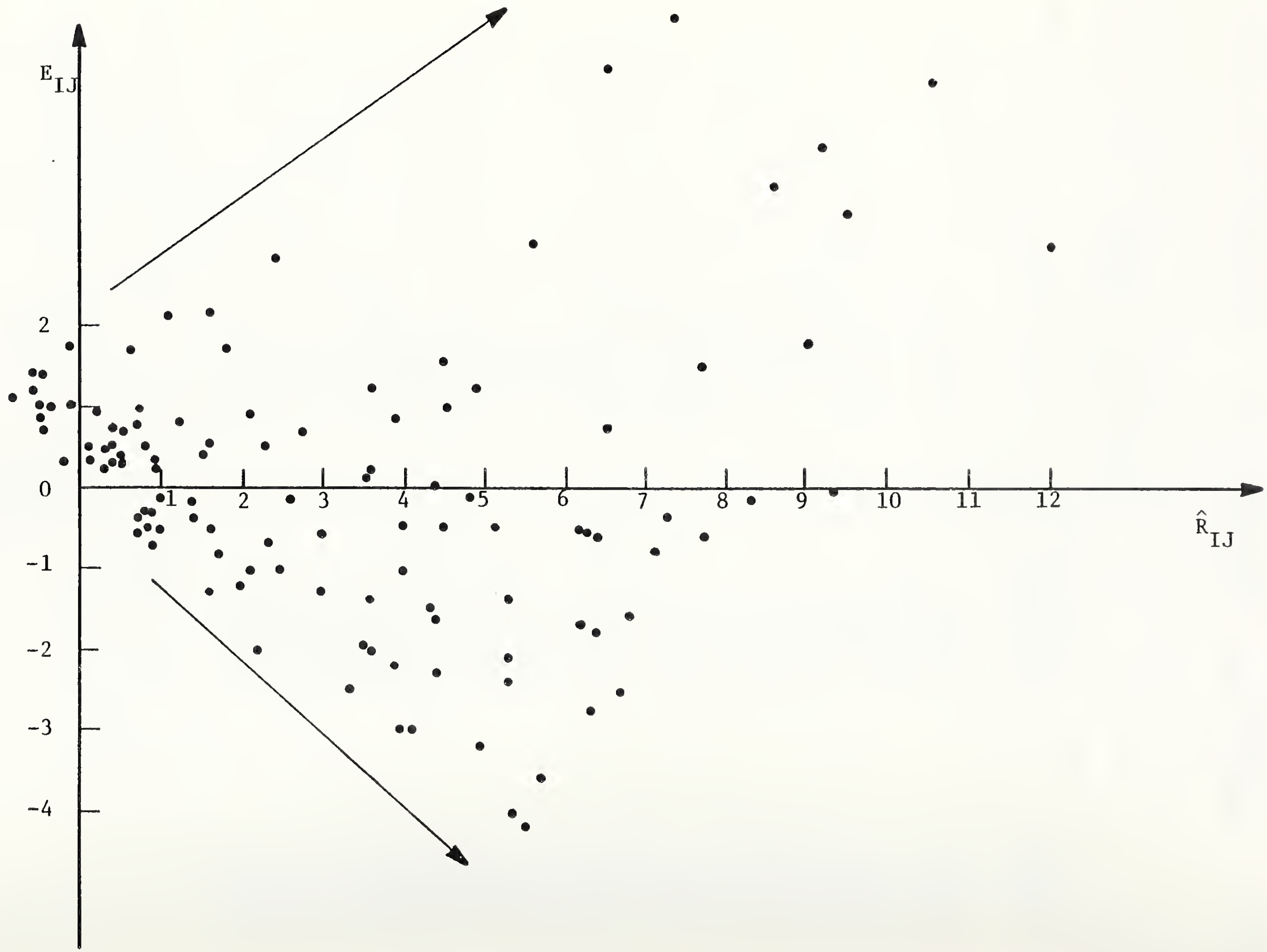


FIGURE 8. PLOT OF THE RESIDUALS, E_{IJ}, VS. THE PREDICTED VALUE, $\hat{R}_{IJ}$

- Figure 9 shows a normal probability plot of ε_{IJ}, in which the cumulative distribution of the standardized residuals is compared against that of a standard normal distirbution, N(0,1). Again, it shows a slight departure from the normality assumption near the lower end of the scale. As normality is a rather robust condition, a slight departure will not hinder the effectiveness of the model.

Figure 10 plots the fitted values, $\hat{R}_{IJ}$, against the original values R_{IJ}. This is done in an attempt to detect any systematic departure of the existing model from the true model. A random distribution of the points around the line $\hat{R}_{IJ} = R_{IJ}$ will give credence that the regression model (2) is indeed suitable. We notice, however, that for the lower values, the $\hat{R}_{IJ}$'s are usually greater than the R_{IJ}'s and the pattern is reverse for the higher values. We are led to believe then that $\hat{R}_{IJ}$ is some function of R_{IJ} and a transformation of the data is necessary to straighten the curve.

Transformation of data to improve Model (2)

Based on the information gleaned from the residual plots and ANOVA results above, a modification of the Model (2) is necessary. Transformation of the data serves several objectives:

- to stabilize the variance of the residuals,
- to improve the normality of the residuals,
- to improve the fitness of the model,

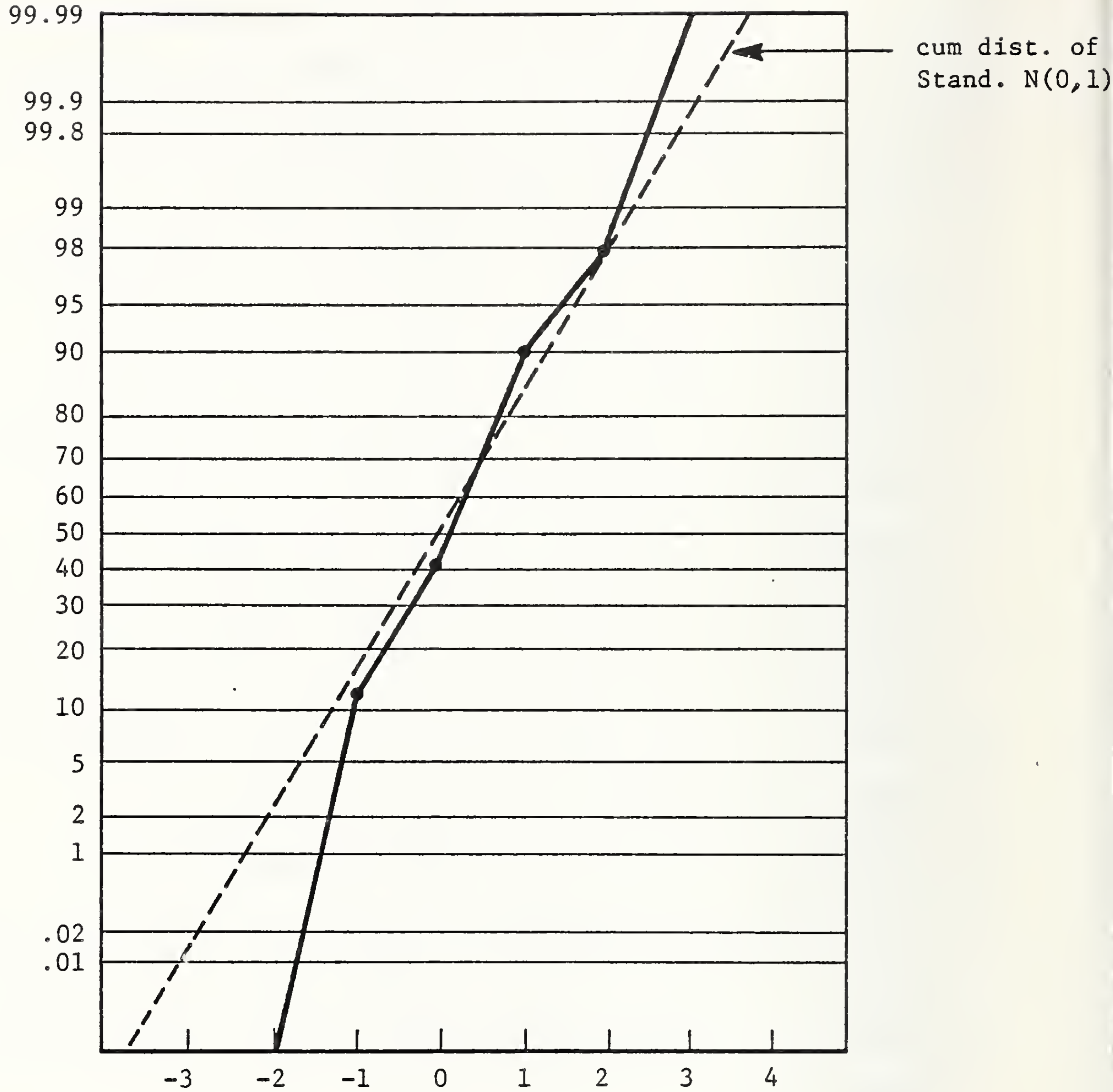


FIGURE 9. NORMALITY PLOT OF THE STANDARDIZED RESIDUALS (UNTRANSFORMED DATA)

38.

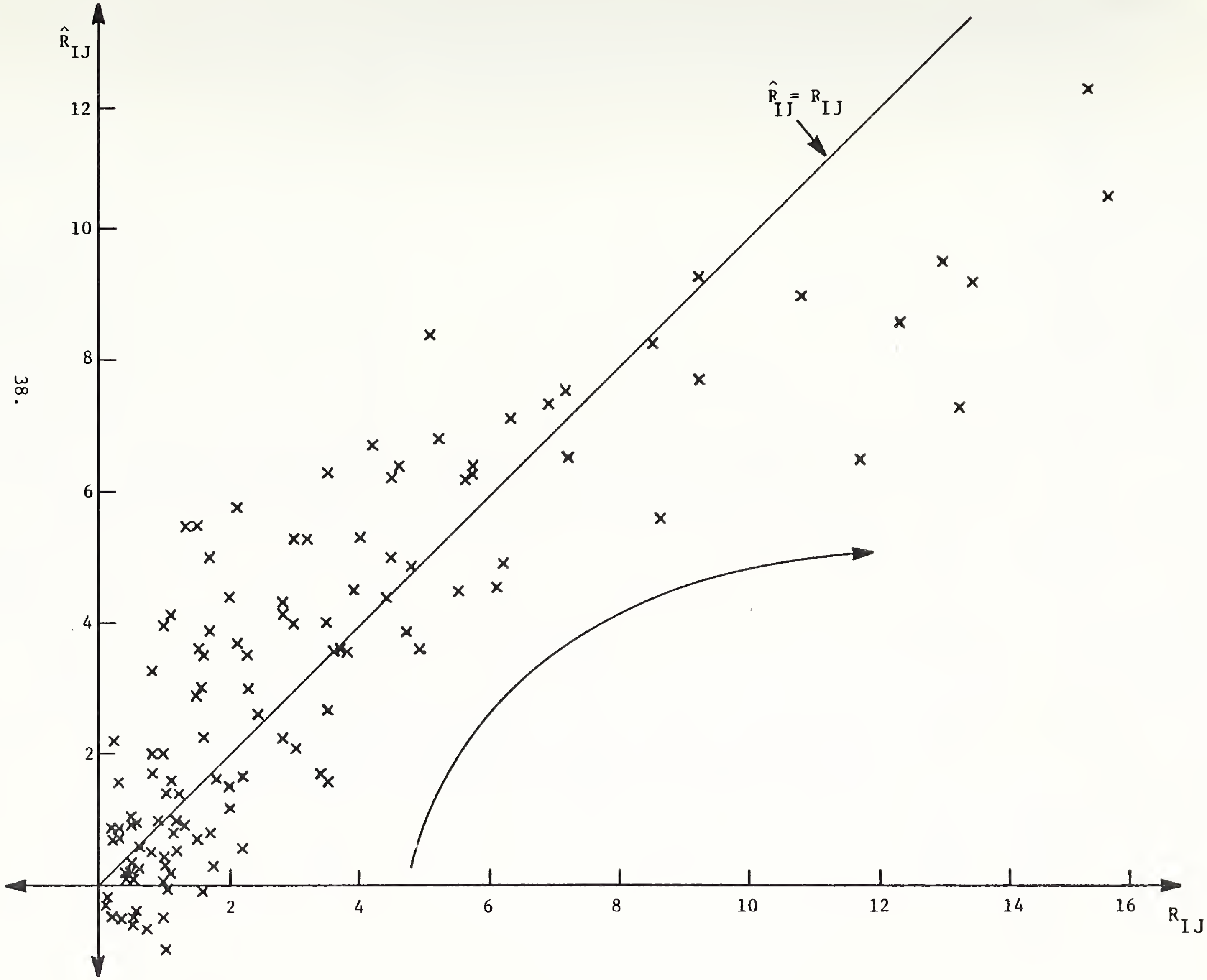


FIGURE 10. PLOT OF PREDICTED VALUES, $\hat{R}_{IJ}$, VS. THE ACTUAL, R_{IJ}
(UNTRANSFORMED DATA)

- to remove or minimize the interaction effect between the station factor and the time factor.

By examining Figure 10, a logarithmic transformation $\acute{R}_{IJ} = \log_e R_{IJ}$, for all pairs seems appropriate. Model (2) thus becomes:

$$\log_e R_{IJ} = u + \sum_i a_i T_i + \sum_j b_i S_j + \varepsilon_{IJ} \qquad (3)$$

Or, equivalently,

$$R_{IJ} = \prod_i \prod_j v\, c_i^{T_i}\, d_j^{S_j}\, \eta_{IJ}$$

$$\text{where } u = \log v,\ a_i = \log c_i,\ b_j = \log d_j$$

$$\varepsilon_{IJ} = \log \eta_{IJ}$$

$$i = 1,\ldots t-1;\ j = 1,2,\ldots,s-1$$

$$I = 1,\ldots t \qquad J = 1,\ldots s$$

It is gratifying to see the improvements in the subsequent regression results of Model (3), which are presented in Table 9. The F statistic (which indicates the statistical significance of the model) has increased from 6.78 to 11.83. The multiple correlation coefficient square shows that the new regression explains about 83% (compared to 73%) of the data variation. The FSTAT has dramatically fallen from 78.11 to a low 4.09. Moreover, the residual plots (Figures 11 - 13) all verify the assumption that Model (3) is based

TABLE 9. ANOVA RESULTS OF RIVON.MTY: MODEL (3) ANALYSIS OF VARIANCE FOR THE REGRESSION (TRANSFORMED DATA)

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F-VALUE
ATTRIBUTABLE TO REGRESSION	34.	123.3282	3.6273	11.8273
DEVIATION FROM REGRESSION	85.	26.0686	0.3067	

INTERCEPT= 0.481
MULTIPLE CORR. COEFF. SQUARE=.82551
STANDARD ERROR OF ESTIMATE= 0.554

VARIABLE	REGR. COEFF.	STD.ERROR, OF COEFF.	COMPUTED T-VALUE
2	-1.1209	0.5709	-1.9634
3	-0.5345	0.3220	-1.6599
4	0.2494	0.2017	1.2364
5	0.1868	0.2017	0.9260
6	-0.0201	0.2163	-0.0929
7	-0.4322	0.2342	-1.8456
8	-0.1861	0.2143	-0.8686
9	-0.3863	0.2152	-1.7954
10	-0.6878	0.2562	-2.6848
11	-0.3178	0.2879	-1.1040
12	-0.2577	0.3338	-0.7719
13	0.1798	0.3240	0.5550
14	-0.2097	0.3364	-0.6234
15	-0.3448	0.2867	-1.2026
16	-0.0186	0.2143	-0.0866
17	-0.1863	0.2143	-0.8696
18	0.1280	0.2522	0.5076
19	0.1820	0.2813	0.6471
20	0.4810	0.2497	1.9262
21	0.2191	0.2497	0.8775
22	0.7460	0.2497	2.9878
23	1.0444	0.2784	3.7517
24	0.6616	0.2497	2.6497
25	0.4111	0.3194	1.2869
26	-0.8815	0.1265	-6.9701
27	-0.9117	0.2604	-3.5014
28	0.0780	0.2057	0.3791
29	-0.3570	0.1906	-1.8732
30	-0.5403	0.1672	-3.2313
31	1.3248	0.1410	9.3927
32	0.7781	0.1668	4.6645
33	0.4194	0.1479	2.8344
34	0.9577	0.1868	5.1263
35	-1.9443	0.2748	-7.0749

THE INTERACTION TEST STAT. , FSTAT: 4.0902

ORIG. RATE	FITTED RATE	RESIDUAL	STAND. RES.
0.00	0.22	0.00	0.00
0.00	0.21	0.00	0.00
0.57	0.57	0.00	0.00
0.00	0.37	0.00	0.00

TABLE 9. (CONT.)

ORIG.RATE	FITTED RATE	RESIDUAL	STAND.RES.
0.00	7.28	0.00	0.00
0.00	4.22	0.00	0.00
0.00	2.94	0.00	0.00
0.00	5.04	0.00	0.00
0.00	0.28	0.00	0.00
0.00	5.68	0.00	0.00
0.00	0.54	0.00	0.00
0.00	0.53	0.00	0.00
1.71	1.42	0.19	0.34
0.00	0.92	0.00	0.00
0.00	0.76	0.00	0.00
0.00	4.93	0.00	0.00
0.00	2.86	0.00	0.00
0.00	1.99	0.00	0.00
2.94	3.42	-0.15	-0.27
0.00	0.19	0.00	0.00
3.71	3.85	-0.04	-0.07
1.05	0.47	0.79	1.43
0.00	0.46	0.00	0.00
1.57	1.24	0.24	0.43
0.00	0.80	0.00	0.00
0.00	0.67	0.00	0.00
0.00	4.31	0.00	0.00
0.00	2.49	0.00	0.00
0.00	1.74	0.00	0.00
1.00	2.99	-1.09	-1.97
0.00	0.16	0.00	0.00
3.58	3.36	0.06	0.11
1.58	0.66	0.88	1.58
0.00	0.64	0.00	0.00
3.46	1.72	0.70	1.27
0.00	1.11	0.00	0.00
0.94	0.92	0.02	0.03
5.24	5.97	-0.13	-0.24
0.00	3.46	0.00	0.00
1.00	2.41	-0.88	-1.59
1.75	4.14	-0.86	-1.55
0.00	0.23	0.00	0.00
6.16	4.66	0.28	0.50
0.69	0.56	0.22	0.39
0.00	0.54	0.00	0.00
2.00	1.45	0.32	0.58
0.00	0.94	0.00	0.00
0.77	0.78	-0.02	-0.03
4.55	5.05	-0.10	-0.19
0.00	2.92	0.00	0.00
1.93	2.04	-0.06	-0.10
2.77	3.50	-0.23	-0.42
0.00	0.19	0.00	0.00
3.47	3.94	-0.13	-0.23
0.92	0.76	0.19	0.34
0.00	0.74	0.00	0.00
0.00	1.99	0.00	0.00
0.00	1.29	0.00	0.00
1.21	1.07	0.12	0.22
6.90	6.91	-0.00	-0.00
0.00	4.00	0.00	0.00
2.45	2.80	-0.13	-0.24
0.00	4.79	0.00	0.00
0.00	0.26	0.00	0.00
4.52	5.40	-0.18	-0.32

TABLE 9. (CONT.)

ORIG.RATE	FITTED RATE	RESIDUAL	STAND.RES.
0.00	0.31	0.00	0.00
0.00	1.98	0.00	0.00
0.00	1.15	0.00	0.00
0.00	0.80	0.00	0.00
0.00	1.37	0.00	0.00
0.00	0.08	0.00	0.00
0.00	1.55	0.00	0.00
0.00	0.39	0.00	0.00
0.00	0.38	0.00	0.00
0.73	1.02	-0.34	-0.61
0.00	0.66	0.00	0.00
0.00	0.55	0.00	0.00
3.22	3.56	-0.10	-0.18
0.00	2.06	0.00	0.00
2.24	1.44	0.44	0.80
0.00	2.47	0.00	0.00
0.00	0.14	0.00	0.00
0.00	2.78	0.00	0.00
1.00	0.86	0.15	0.27
0.00	0.83	0.00	0.00
0.82	2.24	-1.01	-1.82
3.11	1.45	0.76	1.37
0.00	1.21	0.00	0.00
8.53	7.81	0.09	0.16
1.35	4.52	-1.21	-2.18
4.87	3.16	0.43	0.78
11.68	5.41	0.77	1.39
0.30	0.30	0.01	0.02
0.00	6.09	0.00	0.00
0.19	0.81	-1.45	-2.61
0.00	0.78	0.00	0.00
1.14	2.11	-0.61	-1.11
2.39	1.36	0.56	1.01
0.00	1.14	0.00	0.00
13.41	7.33	0.60	1.09
5.75	4.24	0.30	0.55
2.06	2.97	-0.36	-0.66
13.19	5.08	0.95	1.72
0.28	0.28	0.00	0.01
0.00	5.72	0.00	0.00
0.53	0.66	-0.21	-0.39
0.00	0.64	0.00	0.00
0.00	1.71	0.00	0.00
0.84	1.11	-0.28	-0.50
0.00	0.92	0.00	0.00
6.33	5.96	0.06	0.11
2.81	3.45	-0.21	-0.37
5.22	2.41	0.77	1.39
3.90	4.13	-0.06	-0.10
0.21	0.23	-0.08	-0.14
0.00	4.65	0.00	0.00
0.10	0.43	-1.47	-2.65
0.00	0.42	0.00	0.00
0.00	1.13	0.00	0.00
0.78	0.73	0.06	0.11
0.00	0.61	0.00	0.00
4.18	3.95	0.06	0.10
4.73	2.29	0.73	1.31
0.00	1.60	0.00	0.00
4.80	2.74	0.56	1.02
0.16	0.15	0.06	0.11

TABLE 9. (CONT.)

ORIG.RATE	FITTED RATE	RESIDUAL	STAND.RES.
0.83	0.80	0.03	0.06
0.00	0.78	0.00	0.00
0.00	2.10	0.00	0.00
0.00	1.36	0.00	0.00
0.00	1.13	0.00	0.00
12.33	7.30	0.52	0.95
0.00	4.22	0.00	0.00
1.69	2.95	-0.56	-1.01
0.00	5.06	0.00	0.00
0.00	0.28	0.00	0.00
5.70	5.70	0.00	0.00
1.21	1.08	0.11	0.20
0.00	1.05	0.00	0.00
0.00	2.83	0.00	0.00
0.00	1.83	0.00	0.00
1.80	1.52	0.17	0.30
5.14	9.84	-0.65	-1.17
8.57	5.70	0.41	0.74
3.84	3.98	-0.04	-0.06
0.00	6.82	0.00	0.00
0.00	0.37	0.00	0.00
0.00	7.68	0.00	0.00
1.06	0.83	0.24	0.43
0.00	0.81	0.00	0.00
0.00	2.18	0.00	0.00
0.00	1.41	0.00	0.00
1.28	1.17	0.09	0.16
7.11	7.57	-0.06	-0.11
6.25	4.38	0.35	0.64
1.65	3.06	-0.62	-1.12
0.00	5.25	0.00	0.00
0.00	0.29	0.00	0.00
0.00	5.91	0.00	0.00
2.15	1.41	0.42	0.76
0.00	1.37	0.00	0.00
0.00	3.69	0.00	0.00
0.00	2.39	0.00	0.00
2.10	1.99	0.06	0.10
15.56	12.83	0.19	0.35
9.18	7.43	0.21	0.38
2.15	5.19	-0.88	-1.59
0.00	8.89	0.00	0.00
0.00	0.49	0.00	0.00
0.00	10.01	0.00	0.00
2.96	1.90	0.44	0.80
0.00	1.85	0.00	0.00
0.00	4.97	0.00	0.00
0.00	3.22	0.00	0.00
1.52	2.68	-0.57	-1.02
15.23	17.29	-0.13	-0.23
12.87	10.01	0.25	0.45
0.00	6.99	0.00	0.00
0.00	11.98	0.00	0.00
0.00	0.66	0.00	0.00
0.00	13.49	0.00	0.00
1.65	1.30	0.24	0.43
0.00	1.26	0.00	0.00
0.00	3.39	0.00	0.00
0.00	2.19	0.00	0.00
1.50	1.83	-0.20	-0.36
9.23	11.79	-0.24	-0.44

TABLE 9. (CONT.)

ORIG.RATE	FITTED RATE	RESIDUAL	STAND.RES.
0.00	3.08	0.00	0.00
0.57	0.56	0.02	0.04
1.00	0.54	0.62	1.11
0.00	1.45	0.00	0.00
0.00	0.94	0.00	0.00
0.54	0.78	-0.37	-0.67
3.50	5.05	-0.37	-0.66
1.58	2.92	-0.62	-1.11
3.73	2.04	0.60	1.09
3.90	3.50	0.11	0.20
0.00	0.19	0.00	0.00
0.00	3.94	0.00	0.00
0.36	0.46	-0.23	-0.42
0.38	0.44	-0.15	-0.27
0.00	1.19	0.00	0.00
1.15	0.77	0.40	0.73
0.60	0.64	-0.07	-0.12
4.57	4.13	0.10	0.18
1.71	2.39	-0.34	-0.61
2.22	1.67	0.28	0.51
0.00	2.86	0.00	0.00
0.00	0.16	0.00	0.00
0.00	3.23	0.00	0.00
0.39	0.34	0.15	0.27
0.26	0.33	-0.23	-0.41
0.00	0.88	0.00	0.00
0.20	0.57	-1.05	-1.89
0.63	0.47	0.29	0.51
0.00	3.06	0.00	0.00
0.00	1.77	0.00	0.00
2.87	1.24	0.84	1.52
0.00	2.12	0.00	0.00
0.00	0.12	0.00	0.00
0.00	2.39	0.00	0.00
0.48	0.49	-0.02	-0.03
0.52	0.47	0.09	0.17
0.00	1.27	0.00	0.00
0.47	0.82	-0.56	-1.01
1.11	0.69	0.48	0.87
0.00	4.43	0.00	0.00
0.00	2.56	0.00	0.00
0.00	1.79	0.00	0.00
0.00	3.07	0.00	0.00
0.00	0.17	0.00	0.00
0.00	3.46	0.00	0.00
0.54	0.52	0.04	0.08
0.36	0.50	-0.33	-0.60
0.00	1.35	0.00	0.00
1.17	0.87	0.29	0.53
0.00	0.73	0.00	0.00
0.00	4.70	0.00	0.00
0.00	2.72	0.00	0.00
0.00	1.90	0.00	0.00
0.00	3.26	0.00	0.00
0.00	0.18	0.00	0.00
0.00	3.67	0.00	0.00
0.56	0.80	-0.32	-0.58
0.00	0.78	0.00	0.00
3.50	2.09	0.51	0.93
1.12	1.35	-0.19	-0.34
0.00	1.13	0.00	0.00

TABLE 9. (CONT.)

ORIG.RATE	FITTED RATE	RESIDUAL	STAND.RES.
7.17	6.82	0.05	0.09
5.55	4.77	0.15	0.27
0.00	8.17	0.00	0.00
0.00	0.45	0.00	0.00
0.00	9.20	0.00	0.00
0.81	1.01	-0.22	-0.40
0.00	0.98	0.00	0.00
0.00	2.64	0.00	0.00
0.00	1.71	0.00	0.00
0.00	1.42	0.00	0.00
10.80	9.18	0.16	0.29
5.63	5.31	0.06	0.11
0.00	3.71	0.00	0.00
0.00	6.36	0.00	0.00
0.00	0.35	0.00	0.00
0.00	7.16	0.00	0.00
0.00	0.83	0.00	0.00
0.00	0.80	0.00	0.00
0.00	2.16	0.00	0.00
0.00	1.40	0.00	0.00
0.00	1.17	0.00	0.00
0.00	7.53	0.00	0.00
4.36	4.36	0.00	0.00
0.00	3.05	0.00	0.00
0.00	5.22	0.00	0.00
0.00	0.29	0.00	0.00
0.00	5.88	0.00	0.00

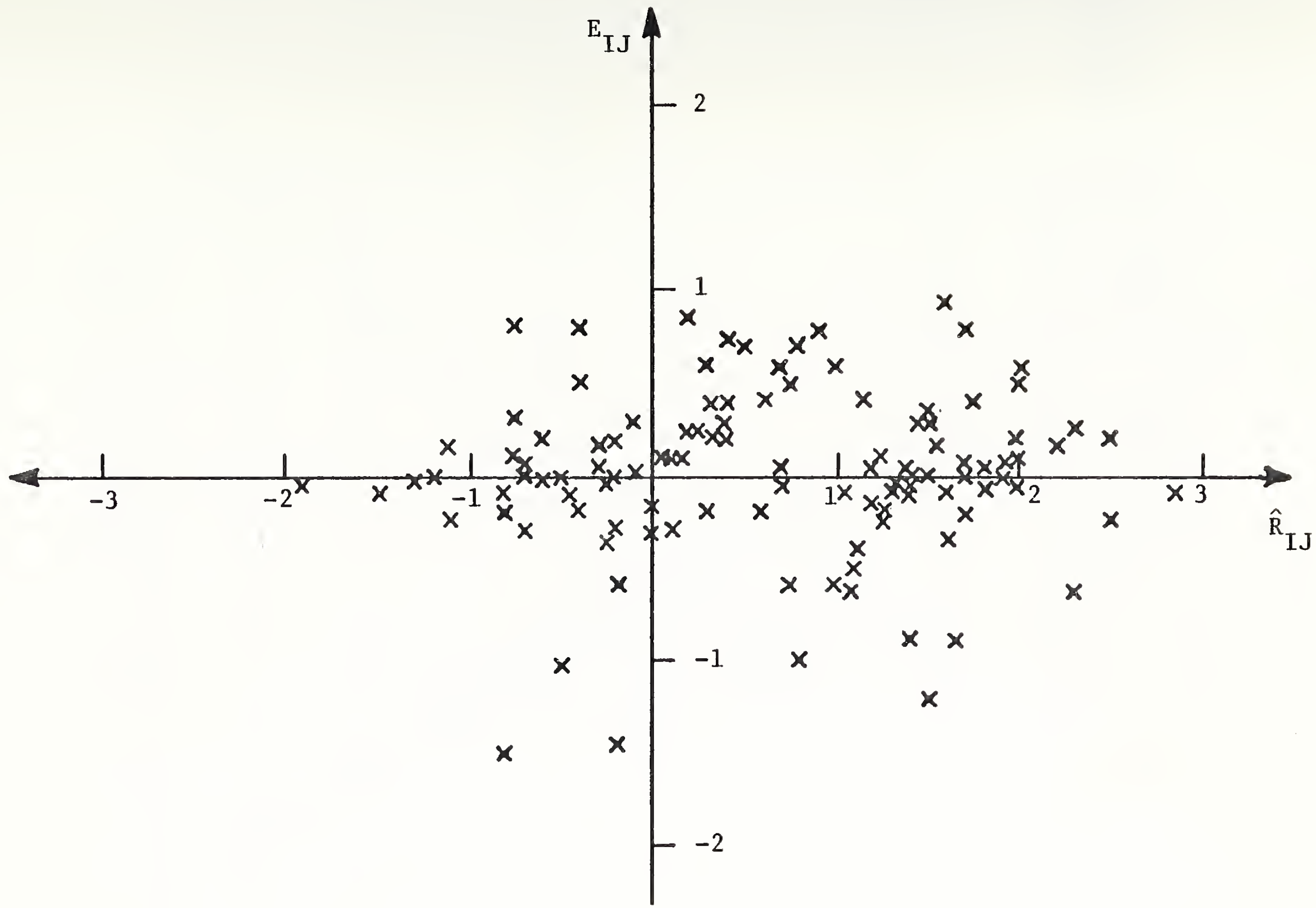


FIGURE 11. PLOT OF THE RESIDUALS, E_{IJ}, VS. THE PREDICTED VALUES, $\hat{R}_{IJ}$ (TRANSFORMED DATA)

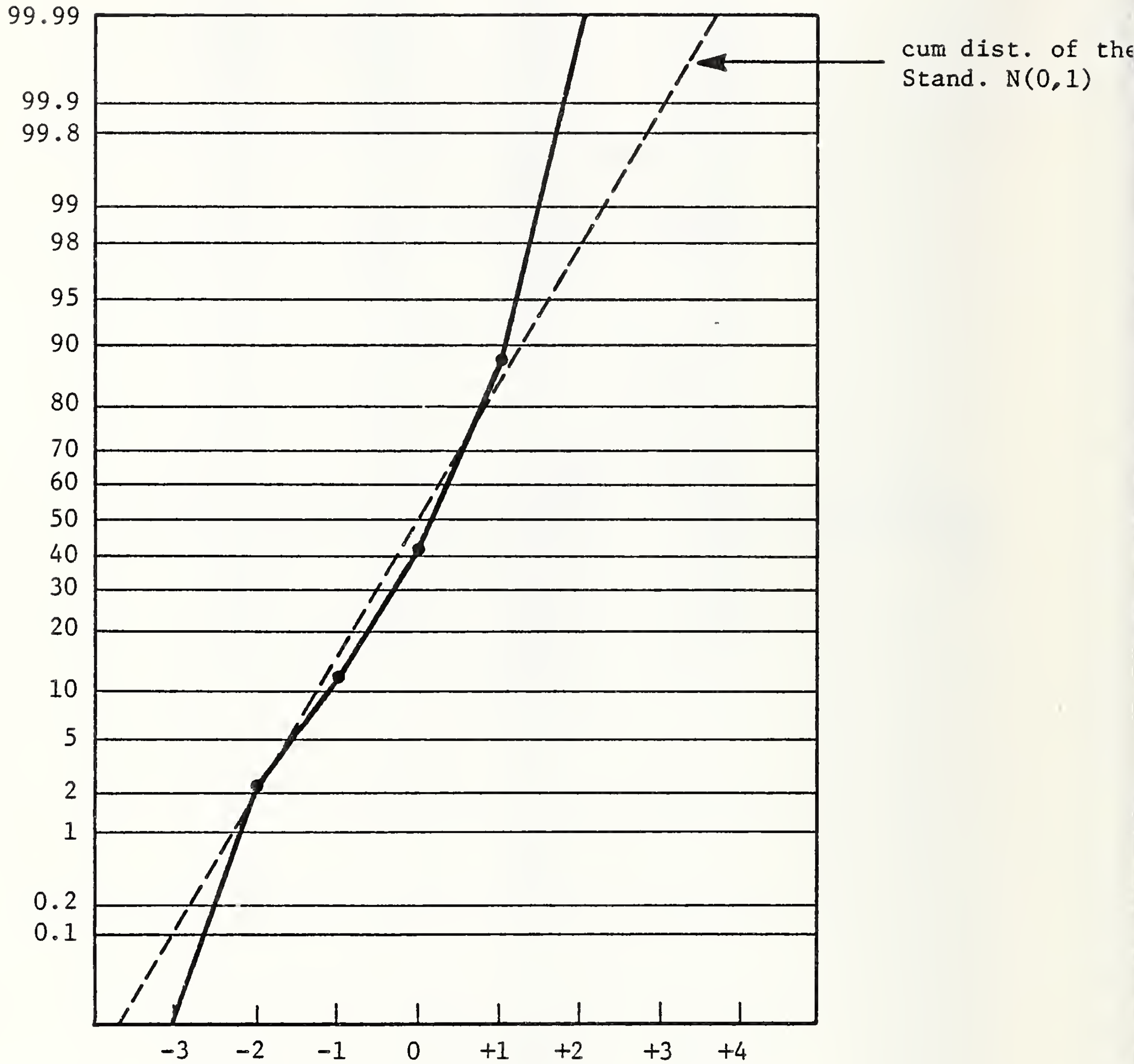


FIGURE 12. NORMALITY PLOT OF THE STANDARDIZED RESIDUALS, E_{IJ} (TRANSFORMED DATA)

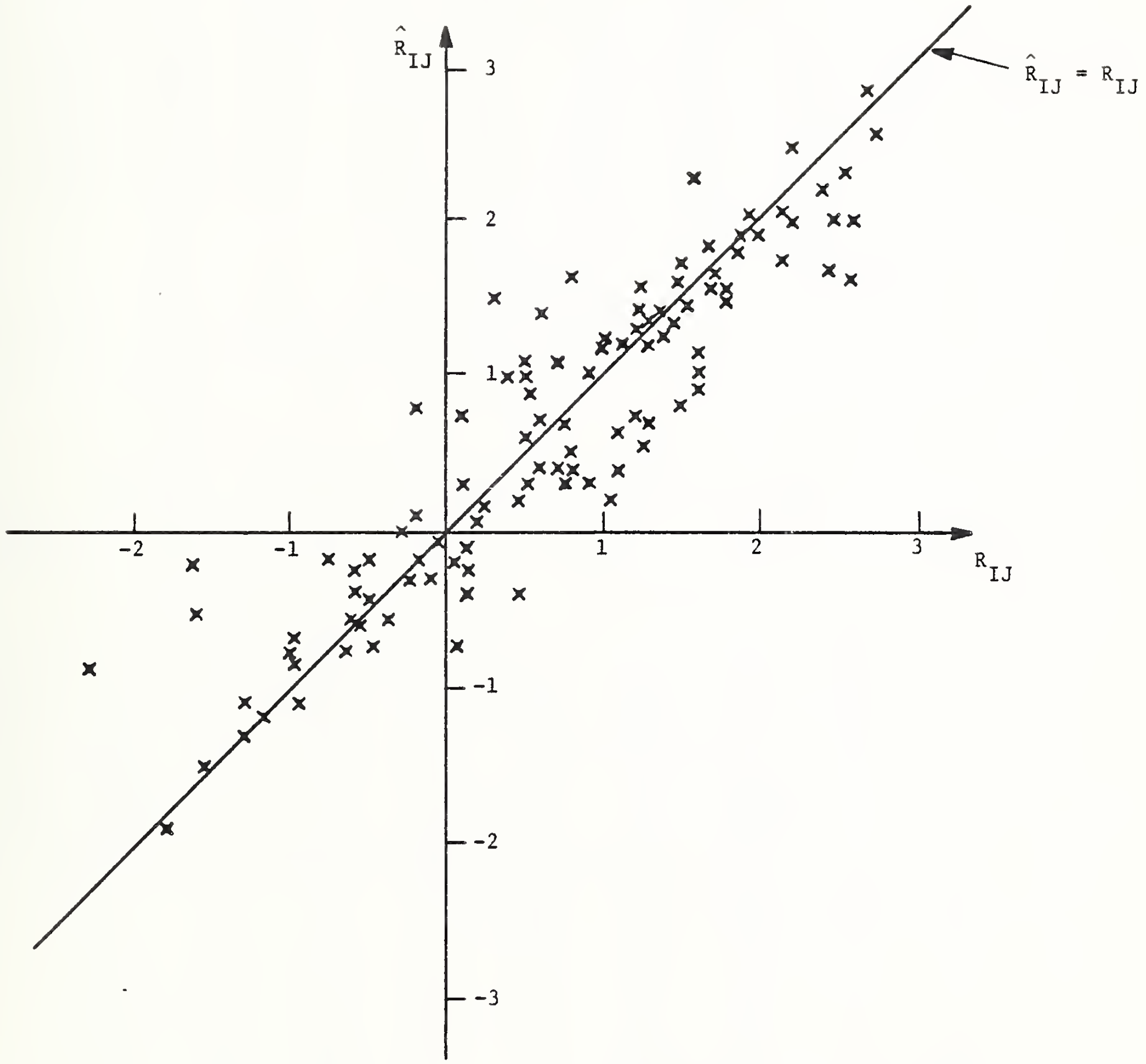


FIGURE 13. PLOT OF THE PREDICTED VALUES, $\hat{R}_{IJ}$, VS. THE ACTUAL, R_{IJ}

on, assumptions such as constant variance and normality of the residuals. Note also that the estimated values are positive throughout while Model (2) produces negative estimates occasionally. At this point, Model (3) is accepted as a reasonably good model for our purposes, and is applied to the other three matrices in Tables 5 through 7. The results are presented in Appendix 13. Tables 10 through 13 present the final matrices with all the empty cells filled with the estimated values derived using Model (3).

VI. Evaluation of Survey Results

Model (3) gives an estimated time series, $\hat{R}_{IJ}$ of passenger rate of flow at the underground stations. It postulates that the expected value of each of these estimated volumes is a multiplicative function of "station" and "time" effects. Hence the variance of these estimates is again a function of the variances and covariances of these estimated effects a_I, or b_J, etc. Since the regression is performed on the transformed data, it is necessary to re-express variances and expected values to their original forms for more meaningful interpretation. Essentially, Model (3) has:

$$\log \hat{R}_{IJ} = \hat{u} + \hat{a}_I + \hat{b}_J$$

$$\text{var}\,(\log \hat{R}_{IJ}) = V(\hat{u}) + V(\hat{a}_I) + V(\hat{b}_J) + 2\,\text{Cov}(\hat{u},\hat{a}_I) + 2\,\text{Cov}(\hat{a}_I,\hat{b}_J) + 2\,\text{Cov}(\hat{u},\hat{b}_I)$$

TABLE 10. ESTIMATED LOADING RATE (ALL RIVERSIDE TRAINS)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.	N. STA.	SCI. PK.	LECH.
700	0,22	0,21	0,57	0,37	0,31	1,98	1,15	0,80	1,37	0,08	1,55
730	0,39	0,38	1,02	0,66	0,55	3,56	2,06	1,44	2,47	0,14	2,78
800	0,86	0,83	2,24	1,45	1,21	7,81	4,52	3,16	5,41	0,30	6,09
830	0,81	0,78	2,11	1,36	1,14	7,33	4,24	2,97	5,08	0,28	5,72
900	0,66	0,64	1,71	1,11	0,92	5,96	3,45	2,41	4,13	0,23	4,65
930	0,43	0,42	1,13	0,73	0,61	3,95	2,29	1,60	2,74	0,15	3,08
1000	0,56	0,54	1,45	0,94	0,78	5,05	2,92	2,04	3,50	0,19	3,94
1030	0,46	0,44	1,19	0,77	0,64	4,13	2,39	1,67	2,86	0,16	3,23
1100	0,34	0,33	0,88	0,57	0,47	3,06	1,77	1,24	2,12	0,12	2,39
1130	0,49	0,47	1,27	0,82	0,69	4,43	2,56	1,79	3,07	0,17	3,46
1200	0,52	0,50	1,35	0,87	0,73	4,70	2,72	1,90	3,26	0,18	3,67
1230	0,80	0,78	2,09	1,35	1,13	7,28	4,22	2,94	5,04	0,28	5,68
1300	0,54	0,53	1,42	0,92	0,76	4,93	2,86	1,99	3,42	0,19	3,85
1330	0,47	0,46	1,24	0,80	0,67	4,31	2,49	1,74	2,99	0,16	3,36
1400	0,66	0,64	1,72	1,11	0,92	5,97	3,46	2,41	4,14	0,23	4,66
1430	0,56	0,54	1,45	0,94	0,78	5,05	2,92	2,04	3,50	0,19	3,94
1500	0,76	0,74	1,99	1,29	1,07	6,91	4,00	2,80	4,79	0,26	5,40
1530	0,80	0,78	2,10	1,36	1,13	7,30	4,22	2,95	5,06	0,28	5,70
1600	1,08	1,05	2,83	1,83	1,52	9,84	5,70	3,98	6,82	0,37	7,68
1630	0,83	0,81	2,18	1,41	1,17	7,57	4,38	3,06	5,25	0,29	5,91
1700	1,41	1,37	3,69	2,39	1,99	12,83	7,43	5,19	8,89	0,49	10,01
1730	1,90	1,85	4,97	3,22	2,68	17,29	10,01	6,99	11,98	0,66	13,49
1800	1,30	1,26	3,39	2,19	1,83	11,79	6,82	4,77	8,17	0,45	9,20
1830	1,01	0,98	2,64	1,71	1,42	9,18	5,31	3,71	6,36	0,35	7,16
1900	0,83	0,80	2,16	1,40	1,17	7,53	4,36	3,05	5,22	0,29	5,88

TABLE 11. ESTIMATED UNLOADING RATES (ALL RIVERSIDE TRAINS)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.
700	2,48	1,20	4,57	2,82	0,50	2,49	0,52	0,06
730	1,38	0,66	3,16	1,56	0,28	1,22	0,29	0,04
800	3,00	1,72	6,68	8,20	0,71	1,97	1,00	0,09
830	4,19	2,27	8,19	7,91	0,94	4,74	1,96	0,06
900	5,05	1,77	6,77	4,26	0,74	3,20	0,57	0,13
930	1,79	0,91	3,47	2,17	0,38	1,76	0,44	0,06
1000	1,33	4,33	6,64	4,09	0,81	3,25	0,81	0,12
1030	1,44	0,66	3,87	2,65	1,65	1,10	0,43	0,07
1100	1,78	0,35	1,64	0,55	0,20	0,89	0,19	0,03
1130	1,55	0,71	3,01	0,80	0,89	1,64	0,34	0,05
1200	1,68	0,73	3,33	2,63	0,36	1,81	0,38	0,06
1230	0,48	0,59	6,00	1,35	0,25	1,23	0,26	0,04
1300	1,64	0,79	3,03	1,87	0,33	1,65	0,34	0,05
1330	1,77	0,79	2,80	1,86	0,33	1,65	0,34	0,05
1400	2,32	1,43	3,15	3,36	0,44	3,48	0,62	0,24
1430	6,42	0,98	2,20	2,30	0,18	2,28	0,42	0,07
1500	3,81	0,88	3,38	2,08	0,34	1,87	0,38	0,03
1530	1,87	1,70	6,50	4,01	0,20	7,00	0,74	0,38
1600	2,66	2,04	7,78	4,80	2,60	3,38	0,57	0,14
1630	3,38	2,47	9,44	5,82	1,09	4,31	1,82	0,16
1700	7,38	2,34	8,95	5,52	1,34	8,76	1,05	0,04
1730	10,04	1,82	6,94	4,28	0,18	5,37	0,87	0,12
1800	8,06	2,84	10,86	6,69	0,94	4,00	0,63	0,50
1830	2,75	1,55	5,91	3,64	0,64	5,70	0,44	0,10
1900	0,34	0,16	0,62	0,38	0,07	0,34	0,07	0,01

TABLE 12. ESTIMATED LOADING RATES (ALL NORTH STATION TRAINS)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.
700	0,32	0,23	0,33	0,19	0,04	0,23	0,05	0,02
730	0,45	0,33	0,47	0,27	0,06	0,33	0,07	0,03
800	2,63	1,94	1,75	1,56	0,36	8,10	0,14	0,17
830	3,06	1,80	3,36	1,84	0,33	2,28	0,13	0,16
900	5,81	2,01	2,82	2,17	0,37	0,63	0,43	0,18
930	1,14	1,08	1,51	0,42	0,20	0,79	0,54	0,13
1000	0,35	0,96	1,18	0,68	0,33	1,21	0,15	0,07
1030	1,14	1,66	1,34	0,92	0,07	1,00	0,33	0,06
1100	3,29	1,13	0,94	1,00	0,16	0,81	0,94	0,12
1130	0,93	1,45	1,26	0,36	0,62	0,95	0,11	0,08
1200	1,75	0,62	0,46	0,56	0,11	0,62	0,10	0,05
1230	1,66	0,89	5,23	0,71	0,16	0,88	0,03	0,08
1300	1,11	0,82	1,15	0,66	0,15	0,81	0,16	0,07
1330	2,94	1,25	1,60	1,01	0,23	1,24	0,24	0,07
1400	3,84	1,30	2,38	1,04	0,24	1,29	0,25	0,04
1430	3,96	1,27	1,74	1,02	0,23	1,26	0,25	0,05
1500	3,00	2,21	3,11	1,78	0,41	2,19	0,43	0,19
1530	6,84	5,05	7,10	4,05	0,93	5,00	0,98	0,44
1600	2,00	2,62	3,68	2,10	0,48	1,80	1,30	0,23
1630	3,67	2,54	4,54	2,59	0,63	5,81	0,24	0,58
1700	2,14	1,36	4,93	1,58	1,09	2,18	0,90	2,22
1730	4,35	4,90	5,67	3,90	0,53	5,70	0,97	0,24
1800	1,08	1,42	1,88	2,50	0,08	1,00	0,72	0,12
1830	0,83	1,13	1,59	1,19	0,25	1,11	0,26	0,10

TABLE 13. ESTIMATED UNLOADING RATES (ALL NORTH STATION TRAINS)

TIME	KEN.	AUD.	COP.	ARL.	BOYL.	PARK	GOV. CTR.	HAY.	N. STA.
700	0,19	0,47	0,47	0,57	0,25	3,30	2,04	0,84	0,67
730	0,39	0,96	0,95	1,15	0,51	6,68	4,12	1,69	1,36
800	1,42	3,49	2,69	4,18	1,85	22,07	20,43	6,16	5,15
830	0,50	1,93	3,96	3,90	1,02	10,69	11,65	3,40	1,09
900	0,38	2,32	2,30	4,67	1,23	13,07	16,97	4,09	3,53
930	0,59	1,00	0,99	2,96	0,53	5,56	7,15	0,47	1,09
1000	0,35	2,67	1,25	1,51	0,89	8,66	6,88	0,94	1,80
1030	0,47	1,45	1,02	1,46	0,52	5,11	2,93	2,22	1,47
1100	0,43	1,45	1,44	1,57	0,61	7,19	3,97	0,49	1,40
1130	0,29	0,68	0,85	0,62	1,12	4,88	1,14	1,24	1,00
1200	0,32	0,97	1,19	0,96	0,52	6,78	5,10	1,72	1,38
1230	0,88	1,42	1,15	1,70	0,75	9,90	4,92	2,51	2,02
1300	0,33	1,43	1,41	1,71	0,76	9,92	6,12	2,51	3,56
1330	0,50	0,78	0,68	0,93	0,41	5,39	3,33	0,50	2,14
1400	1,09	1,75	2,00	2,10	0,93	12,19	7,52	2,39	1,82
1430	1,04	1,41	0,72	1,69	0,75	9,82	6,06	2,26	2,36
1500	0,55	1,35	0,86	1,61	0,71	9,38	5,79	3,69	1,92
1530	0,60	1,48	1,47	1,78	0,79	10,33	6,37	2,62	2,11
1600	0,29	1,02	1,01	1,23	0,54	8,17	5,52	1,81	1,46
1630	0,39	0,85	1,21	1,47	0,38	16,22	4,79	3,96	1,74
1700	0,23	0,71	1,09	0,50	0,74	10,30	4,67	9,04	1,56
1730	0,39	0,90	1,28	0,94	0,41	12,33	5,34	9,05	1,83
1800	0,50	0,77	1,00	0,88	0,46	7,76	3,62	3,41	1,44
1830	1,37	0,80	0,79	0,85	0,25	3,66	2,39	1,41	1,14

where Var(log $\hat{R}_{IJ}$) represents the variance of the present estimate log $\hat{R}_{IJ}$ from the true mean. Since an actual observed rate of flow varies from the true mean value with variance σ^2, a predicted value of any individual observation will have variance (σ^2 + Var(log $\hat{R}_{IJ}$)). To re-express the transformed data to their original form,

$$\hat{R}_{IJ} = e^{\log \hat{R}_{IJ}}$$

$$\mathrm{Var}(\hat{R}_{IJ}) = (\hat{R}_{IJ})^2 \ \mathrm{var}(\log \hat{R}_{IJ})$$

and the variance of a predicted individual observation is $(\hat{R}_{IJ})^2$ (σ^2 + Var (log $\hat{R}_{IJ}$)). Such is also the variance of the distribution of passenger flow to be calibrated into the simulation model to generate new time series. We choose Park Street Station to illustrate. Figure 14 represents three time series, namely the actual collected data, the estimated data derived from Model (3), and the 95% confidence bound not on the estimated series but rather on a future predicted observation. That is, model (3) gives only an estimated average rate of flow, when given the "station" and "time" are fixed, but in 95 cases out of 100, an individual observation will fall within the confidence bound. The wide confidence band indicates that any actual observed series of passenger flow data is expected to behave rather sporadically around the means.

VII. Conclusion

In improving the operational performance of the Light Rail Vehicles in terms of maximizing the utility of the LRV

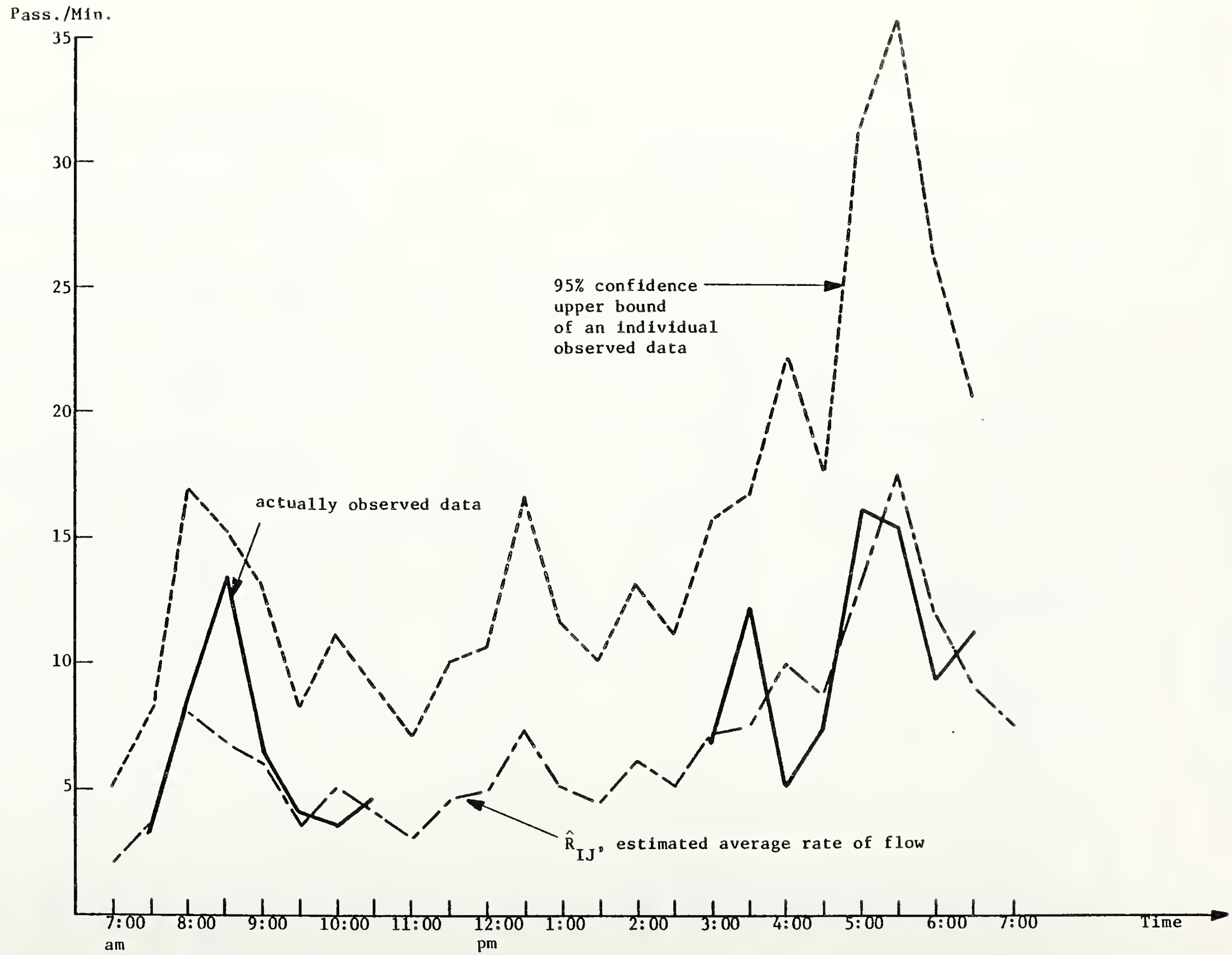


FIGURE 14. PROFILE OF LOADING PASSENGERS AT PARK STREET STATION, 1978 (TO RIVERSIDE)

cars and reducing passengers' waiting time, information about the present distribution of ridership of a transit line is essential. This study has shown that sufficiently accurate and quantitative knowledge about such distributions at different stations can be gained without expending huge amounts of labor and financial resources. Through the use of sampling techniques, from sampling days/shifts and stations to sampling cars or doors of cars, and through the application of a simple statistical model in which "station" and "time" are the determining factors, a representative daily ridership profile for each station has been obtained. However, there is still room for improvement. For example, the problem of sample size has not been addressed. Had a replicated sampling scheme been followed, that is, if for each station-time period combination, more than one observation of the passenger rate of flow were taken, it would be possible to estimate the magnitude of the interaction effect and the pure random error, σ^2, separately. Also, a cursory look at Table 11, the estimated unloading passenger rate for the Riverside Train reveals abnormally high estimates for Copley during the afternoon rush hours. The environment (mostly business establishments) around the locality does not command such high return rates of passengers.

Validation plans are underway to verify or modify our current estimates. Additional data for the 12:00 - 1:30 period needs to be gathered. However, instead of sampling all stations, it is proposed that only three to four stations

should be observed, and a continuous time series of passenger data be collected. We also need to examine which station and time period in which interaction plays an important part. Also, it is discovered from the data sheets that some surveyors often do not systematically sample the cars when counting passengers from all cars becomes unmanageable. This should be emphasized to assure the representativeness of the collected data, since the distribution of people loading in and out of the two cars is often not uniform. Depending on their proximity to the subway entrance, one car usually gets more passengers than another.

Finally, a word should be said about the estimated total volume of passengers. An earlier study on surface stations has estimated that the daily total number of patrons from the surface section of the Riverside line trains is only approximately 6,800.[1] It would be interesting to see if the data one year later (underground stations) in this study corroborates previous findings. We approximate the total daily volume of passengers going outbound to beyond Kenmore as:

$$\text{Total RIVON outbound} = 30\left(\sum_{I,J} \hat{R}_{IJ_{RIVON}} - \sum_{I,J} \hat{R}_{IJ_{RIVOFF}}\right).$$

[1]Kwok, Betty, "MBTA Passenger Demand Analyses, 1977," U.S. Department of Transportation, Urban Mass Transportation Administration, UMTA-MA-06-0074-81-2, August 1981.

This is equivalent to multiplying the "net on" rates (passenger/min.) by 30 (minutes). Similarly, the total number of passengers from the surface stations going inbound to the tunnels is approximated as:

$$\text{TOTAL RIVON inbound} - 30 \left(\sum_{I,J} \hat{R}_{IJ_{NOROFF}} - \sum_{I,J} \hat{R}_{IJ_{NORON}} \right) .$$

These two statistics are 9,700 and 10,000 respectively. Has the ridership really increased 40%? Statistical variations around earlier estimates and current estimates prohibit such a straightforward conclusion. We can only be contented by the apparent correspondence between the total outbound and inbound volumes, which adds to the credibility and reliability of our passenger flow estimates.

APPENDIX 1
SURVEYOR DATA

DATE 7-5/78 Initial of Observer [illegible]

STATION [illegible]

Remarks:

indicate if count is not for entire train
1. car number - C1, C2, C3
2. door number - D1, D2, D3

indicate any unusual circumstance such as big groups, etc.

☐ Lechmere → Riverside
☑ Riverside → Lechmere

Time of Arrival	LINE	Car Length	PCC / LRV	PASS. ON	PASS. OFF	REMARKS
9:1[illegible]	—	2	P[illegible]	12	22	C1
9:14	GC	1	PCC			
9:15	L	1	LRV	5	12	C1 D1
9:15	GC	1	PCC			
9:16	N	2	LRV	0	9	C1 D1
9:17	L	2	PCC	1	4	C1
9:17	L	2	LRV	0	10	C1 D1
9:19	L	1	LRV	1	58	
9:19	L	2	PCC	0	3	C1 C2
9:20	GC	1	PCC			
9:21	GC	1	PCC			
9:23	L	3	PCC	5	63	C-1
9:24	L	2	PCC	8	25	C1
9:25	N	2	LRV	0	11	C1 D1
9:26	GC	1	PCC			
9:26	GC	1	PCC			
9:27	L	3	PCC	24	20	C-1
9:32	L	2	PCC	3	42	C-2
9:33	GC	1	PCC			
9:34	L	2	PCC	6	12	C1
9:35	GC	1	PCC			
9:37	N	2	LRV	0	54	C2 D1
9:38	GC	2	LRV			

DATE 5/26/78

STATION Government C.

Initial of Observer [illegible]

- [x] Lechmere → Riverside
- [ ] Riverside → Lechmere

Remarks:

indicate if count is not for entire train
1. car number - C1, C2, C3
2. door number - D1, D2, D3

indicate any unusual circumstance such as big groups, etc.

Local arriving

Time of Arrival	LINE	Car Length	PCC / LRV	PASS. ON	PASS. OFF	REMARKS
5:05	R	2	LRV	58	2	C1
5:05	R	1	LRV	35	1	C1 D1
5:07	[illegible]	2	Pcc			
5:10	R	2	Pcc			
5:11	[illegible]	2	Pcc			
5:12	[illegible]	1	Pcc			
5:13	R	2	LRV	21	1	C1
5:14	R	1	LRV	[illegible]	[illegible]	[illegible]
5:16	[illegible]	2	Pcc	[illegible]	[illegible]	C1
5:17	R	2	LRV	[illegible]	[illegible]	C1
5:22	[illegible]	1	Pcc			
5:23	R	2	Pcc			
[illegible]	[illegible]	2	Pcc			
5:27	[illegible]	1	Pcc			
[illegible]	[illegible]	[illegible]	Pcc			
[illegible]	[illegible]	[illegible]	Pcc			
[illegible]	R	2	LRV	53	[illegible]	C1
[illegible]	[illegible]	1	Pcc			
[illegible]	[illegible]	2	Pcc			
[illegible]	[illegible]	1	Pcc			
[illegible]	R	[illegible]	LRV	32	[illegible]	C1
[illegible]	[illegible]	2	Pcc			
5:37	[illegible]	2	LRV			

APPENDIX 2
MBTA FILE STRUCTURE

```
780522PARK          0750H 1PCC
780522PARK          0751BC1LRV
780522PARK          0751H 1LRV
780522PARK          0752H 1PCC
780522PARK          0753R 2LRV 20  9 X X
780522PARK          0756CC1LRV
780522PARK          0757R 2LRV  0  0
780522PARK          0757H 1PCC
780522PARK          0800CC2PCC
780522PARK          0802R 2LRV  2  4 X X
780522PARK          0804H 1PCC
780522PARK          0805CC2PCC
780522PARK          0805BC3PCC
780522PARK          0806H 1LRV
780522PARK          0809K 1LRV
780522PARK          0810BC2PCC
780522PARK          0812R 2LRV 23  3 X X
780522PARK          0813CC2PCC
780522PARK          0815H 1PCC
780522PARK          0817R 1LRV 22 13 X X
780522PARK          0815H 1PCC
780522PARK          0822H 1PCC
780522PARK          0824R 2LRV 35  4 X  X
780522PARK          0826H 1PCC
780522PARK          0827H 1PCC
780522PARK          0831H 1LRV
780522PARK          0836H 1PCC
780522PARK          0837BC3PCC
780522PARK          0838CC2LRV
780522PARK          0839CC2PCC
780522PARK          0840R 2LRV 19  8 X  X
780522PARK          0841CC2PCC
780522PARK          0842BC3PCC
780522PARK          0842BC3
780522PARK          0843N 1LRV
780522PARK          0844H 1PCC
780522PARK          0844CC2PCC
780522PARK          0845H 1LRV
780522PARK          0845CC2PCC
780522PARK          0846H 1PCC
780522PARK          0847R 2LRV 10 11 X  X
780522PARK          0848R 2LRV  5  0 X  X
780522PARK          0849CC2PCC
780522PARK          0851H 1PCC
780522PARK          0851N 1LRV
780522PARK          0854R 2LRV  1  1
780522PARK          0854H 1LRV
780522PARK          0856BC2PCC
780522PARK          0859H 1PCC
780522PARK          0900H 1PCC
780522PARK          0900H 1PCC
780522PARK          0901CC2PCC
780522PARK          0902H 1LRV
780522PARK          0902BC3PCC
780522PARK          0904N 1LRV
780522PARK          0904H 1PCC
780522PARK          0907K 1LRV
780522PARK          0908CC2PCC
780522PARK          0906BC1LRV
780522PARK          0909H 2LRV
780522PARK          0910R 2LRV 13  4 X  X
```

APPENDIX 3
PROGRAM EXTRAC

```
TYPE EXTRAC
   OPEN MBTA.
   F STATION EQ "ARLINGTON".
   INI 1 ARLING.TON.
   SORT BY MAYDAY LINE TIME TYPEOFCAR TRANSIZE.
   PRINT ON 1 MAYDAY TIME LINE TRAINSIZE TYPEOFCAR PASSON PASSOFF $
   CAR1 CAR2 CAR3 DOOR1 DOOR2 DOOR3 COLLECT FMT D4 I4 A8 I1 A3 &
   I3 I3 F1 A1 A1 A1 A1 A1 27 I1 END.
   QUIT.
```

APPENDIX 4
PROGRAMS EDIT AND EDIT1

PROGRAM EDIT

```
      INTEGER LINE, CT, CAR1, CAR2, CAR3, D1, D2, D3
      CALL IFILE(21,'KEMORE.')
      CALL OFILE(22,'STRAI.')
1     IC1D1=0
      IC1D2=0
      IC1D3=0
      IC2D1=0
      IC2D2=0
      IC2D3=0
      IC3D1=0
      IC3D2=0
      IC3D3=0
      READ(21,5,END=100)IDATE,ITIME,LINE,ITS,CT,ION,IOFF,CAR1,
     2 CAR2,CAR3,D1,D2,D3,ICOL
5     FORMAT(I8,I4,A2,I1,A3,2(I3),6(A1),2X,I1)
      IF(CT.EQ.'PCC')GO TO 25
      IF(CAR1.EQ.'X'. AND. CAR2.EQ.'X'. AND. D1.EQ.'X'.
     2 AND .D3.EQ.'X') GO TO 70
      IF(CAR1.NE.'X')GO TO 7
      IF(D1.EQ.'X')IC1D1=1
      IF(D2.EQ.'X')IC1D2=1
      IF(D3.EQ.'X')IC1D3=1
      IF(D1.NE.'X'.AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 6
      GO TO 7
6     IC1D1=1
      IC1D2=1
      IC1D3=1
7     IF(CAR2.NE.'X')GO TO 9
      IF(D1.EQ.'X')IC2D1=1
      IF(D2.EQ.'X')IC2D2=1
      IF(D3.EQ.'X')IC2D3=1
      IF(D1.NE.'X'.AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 8
      GO TO 9
8     IC2D1=1
      IC2D2=1
      IC2D3=1
9     IF(CAR1.NE.'X'.AND.CAR2.NE.'X'.AND.D1.NE.'X'.
     2 AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 10
      GO TO 12
10    IC1D1=1
      IC1D2=1
      IC1D3=1
      IC2D1=1
      IC2D2=1
      IC2D3=1
12    IF((IC1D1+IC1D2+IC1D3+IC2D1+IC2D2+IC2D3).GT.0)GO TO 75
      WRITE(5,14)ITIME,IDATE
14    FORMAT('CANNOT ALLOCATE COUNT TO DOOR AT',1X,I4,
     2 1X,'ON',1X,I8)
      GO TO 75
25    IF(CAR1.NE.'X')GO TO 27
      IF(D1.EQ.'X')IC1D1=1
      IF(D2.EQ.'X')IC1D2=1
      IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 26
      GO TO 27
26    IC1D1=1
      IC1D2=1
27    IF(CAR2.NE.'X')GO TO 29
      IF(D1.EQ.'X')IC2D1=1
      IF(D2.EQ.'X')IC2D2=1
      IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 28
```

```
        GO TO 29
28      IC2D1=1
        IC2D2=1
29      IF(CAR3.NE.'X')GO TO 31
        IF(D1.EQ.'X')IC3D1=1
        IF(D2.EQ.'X')IC3D2=1
        IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 30
        GO TO 31
30      IC3D1=1
        IC3D2=1
31      IF(CAR1.NE.'X'.AND.CAR2.NE.'X'.AND.ITS.EQ.2.AND.D1.NE.'X'.
        2 AND.D2.NE.'X')GO TO 33
        GO TO 34
33      IC1D1=1
        IC1D2=1
        IC2D1=1
        IC2D2=1
34      IF(CAR1.NE.'X'.AND.CAR2.NE.'X'.AND.CAR3.NE.'X'.AND.
        2  ITS.EQ.3.AND.D1.NE.'X'.AND.D2.NE.'X')GO TO 37
        GO TO 38
37      IC1D1=1
        IC1D2=1
        IC2D1=1
        IC2D2=1
        IC3D1=1
        IC3D2=1
38      IF((IC1D1+IC1D2+IC2D1+IC2D2+IC3D1+IC3D2).GT.0)GO TO 75
        WRITE(5,14)ITIME,IDATE
        GO TO 75
70      IC1D3=1
        IC2D1=1
75      WRITE(22,80)IDATE,ITIME,LINE,ITS,CT,ION,IOFF,
        2 IC1D1,IC1D2,IC1D3,IC2D1,IC2D2,IC2D3,IC3D1,IC3D2,IC3D3,ICOL
80      FORMAT(I8,I4,A2,I1,A3,I3,I3,9(I1),2X,I1)
        GO TO 1
100     END
```

PROGRAM EDIT1

Program EDIT1 is similar to EDIT but is used for trains opening doors on both sides.

```
      INTEGER LINE, CT, CAR1, CAR2, CAR3, D1, D2, D3,SIDE
      CALL IFILE(21,'KEMORE.')
      CALL OFILE(22,'STRAI.')
10    IC1D1L=0
      IC1D2L=0
      IC1D3L=0
      IC2D1L=0
      IC2D2L=0
      IC2D3L=0
      IC3D1L=0
      IC3D2L=0
      IC3D3L=0
      IC1D1R=0
      IC1D2R=0
      IC1D3R=0
      IC2D1R=0
      IC2D2R=0
      IC2D3R=0
      IC3D1R=0
      IC3D2R=0
      IC3D3R=0
      READ(21,50,END=1000)IDATE,ITIME,LINE,ITS,CT,ION,IOFF,CAR1,
     2 CAR2,CAR3,D1,D2,D3,ICCL,SIDE
50    FORMAT(I8,I4,A2,I1,A3,2(I3),6(A1),2X,I1,A1)
      IF(CT.EQ.'PCC')GO TO 250
      IF(CAR1.EQ.'X'. AND. CAR2.EQ.'X'. AND. D1.EQ.'X'.
     2 AND .D3.EQ.'X') GO TO 700
      IF(CAR1.NE.'X')GO TO 70
      IF(SIDE.NE.'L')GO TO 61
      IF(D1.EQ.'X')IC1D1L=1
      IF(D2.EQ.'X')IC1D2L=1
      IF(D3.EQ.'X')IC1D3L=1
      GO TO 70
      IF(D1.NE.'X'.AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 60
      GO TO 70
60    IC1D1L=1
      IC1D2L=1
      IC1D3L=1
      GO TO 70
61    IF(D1.EQ.'X')IC1D1R=1
      IF(D2.EQ.'X')IC1D2R=1
      IF(D3.EQ.'X')IC1D3R=1
      IF(D1.NE.'X'.AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 62
      GO TO 70
62    IC1D1R=1
      IC1D2R=1
      IC1D3R=1
70    IF(CAR2.NE.'X')GO TO 90
      IF(SIDE.NE.'L')GO TO 81
      IF(D1.EQ.'X')IC2D1L=1
      IF(D2.EQ.'X')IC2D2L=1
      IF(D3.EQ.'X')IC2D3L=1
      IF(D1.NE.'X'.AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 80
      GO TO 90
80    IC2D1L=1
      IC2D2L=1
      IC2D3L=1
      GO TO 90
81    IF(D1.EQ.'X')IC2D1R=1
      IF(D2.EQ.'X')IC2D2R=1
      IF(D3.EQ.'X')IC2D3R=1
```

```
      IF(D1.NE.'X'.AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 82
      GO TO 90
82    IC2D1R=1
      IC2D2R=1
      IC2D3R=1
90    IF(CAR1.NE.'X'.AND.CAR2.NE.'X'.AND.D1.NE.'X'.
     2 AND.D2.NE.'X'.AND.D3.NE.'X')GO TO 100
      GO TO 120
100   IF(SIDE.NE.'L')GO TO 101
      IC1D1L=1
      IC1D2L=1
      IC1D3L=1
      IC2D1L=1
      IC2D2L=1
      IC2D3L=1
      GO TO 120
101   IC1D1R=1
      IC1D2R=1
      IC1D3R=1
      IC2D1R=1
      IC2D2R=1
      IC2D3R=1
120   IF((IC1D1L+IC1D2L+IC1D3L+IC2D1L+IC2D2L+IC2D3L).GT.0.OR.
     2 (IC1D1R+IC1D2R+IC1D3R+IC2D1R+IC2D2R+IC2D3R).GT.0)
     2 GO TO 750
      WRITE(5,140)ITIME,IDATE
140   FORMAT('CANNOT ALLOCATE COUNT TO DOOR AT',1X,I4,
     2 1X,'ON',1X,I8)
      GO TO 750
250   IF(CAR1.NE.'X')GO TO 270
      IF(SIDE.NE.'L')GO TO 265
      IF(D1.EQ.'X')IC1D1L=1
      IF(D2.EQ.'X')IC1D2L=1
      IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 260
      GO TO 270
260   IC1D1L=1
      IC1D2L=1
      GO TO 270
265   IF(D1.EQ.'X')IC1D1R=1
      IF(D2.EQ.'X')IC1D2R=1
      IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 266
      GO TO 270
266   IC1D1R=1
      IC1D2R=1
270   IF(CAR2.NE.'X')GO TO 290
      IF(SIDE.NE.'L')GO TO 281
      IF(D1.EQ.'X')IC2D1L=1
      IF(D2.EQ.'X')IC2D2L=1
      IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 280
      GO TO 290
280   IC2D1L=1
      IC2D2L=1
      GO TO 290
281   IF(D1.EQ.'X')IC2D1R=1
      IF(D2.EQ.'X')IC2D2R=1
      IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 282
      GO TO 290
282   IC2D1R=1
      IC2D2R=1
290   IF(CAR3.NE.'X')GO TO 310
      IF(SIDE.NE.'L')GO TO 305
```

```
        IF(D1.EQ.'X')IC3D1L=1
        IF(D2.EQ.'X')IC3D2L=1
        IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 300
        GO TO 310
300     IC3D1L=1
        IC3D2L=1
        GO TO 310
305     IF(D1.EQ.'X')IC3D1R=1
        IF(D2.EQ.'X')IC3D2R=1
        IF(D1.NE.'X'.AND.D2.NE.'X')GO TO 306
        GO TO 310
306     IC3D1R=1
        IC3D2R=1
310     IF(CAR1.NE.'X'.AND.CAR2.NE.'X'.AND.ITS.EQ.2.AND.D1.NE.'X'.
        2 AND.D2.NE.'X')GO TO 330
        GO TO 340
330     IF(SIDE.NE.'L')GO TO 335
        IC1D1L=1
        IC1D2L=1
        IC2D1L=1
        IC2D2L=1
        GO TO 340
335     IC1D1R=1
        IC1D2R=1
        IC2D1R=1
        IC2D2R=1
340     IF(CAR1.NE.'X'.AND.CAR2.NE.'X'.AND.CAR3.NE.'X'.AND.
        2  ITS.EQ.3.AND.D1.NE.'X'.AND.D2.NE.'X')GO TO 370
        GO TO 380
370     IF(SIDE.NE.'L')GO TO 375
        IC1D1L=1
        IC1D2L=1
        IC2D1L=1
        IC2D2L=1
        IC3D1L=1
        IC3D2L=1
        GO TO 380
375     IC1D1R=1
        IC1D2R=1
        IC2D1R=1
        IC2D2R=1
        IC3D1R=1
        IC3D2R=1
380     IF((IC1D1L+IC1D2L+IC2D1L+IC2D2L+IC3D1L+IC3D2L).GT.0.
        2 OR.(IC1D1R+IC1D2R+IC2D1R+IC2D2R+IC3D1R+IC3D2R).GT.0)
        2 GO TO 750
        WRITE(5,140)ITIME,IDATE
        GO TO 750
700     IF(SIDE.NE.'L')GO TO 705
        IC1D3L=1
        IC2D1L=1
        GO TO 750
705     IC1D3R=1
        IC2D1R=1
750     WRITE(22,800)IDATE,ITIME,LINE,ITS,CT,ION,IOFF,
        2 IC1D1L,IC1D2L,IC1D3L,IC2D1L,IC2D2L,IC2D3L,
        2 IC3D1L,IC3D2L,IC3D3L,IC1D1R,IC1D2R,IC1D3R,IC2D1R,IC2D2R,
        2 IC2D3R,IC3D1R,IC3D2R,IC3D3R,ICOL
800     FORMAT(I8,I4,A2,I1,A3,I3,I3,18(I1),2X,I1)
        GO TO 10
1000    END
```

APPENDIX 5
PROGRAMS EDIT2 AND EDIT3

PROGRAM EDIT2

```
      INTEGER LINE(0:4),CT(0:4)
      DIMENSION IDATE(0:4),IHR(0:4),IMIN(0:4),ITS(0:4),
     2 ION(0:4),IOFF(0:4),IC1D1(0:4),IC1D2(0:4),IC1D3(0:4),
     2 IC2D1(0:4),IC2D2(0:4),IC2D3(0:4),IC3D1(0:4),IC3D2(0:4),
     2 IC3D3(0:4),ICOL(0:4),ICOUNT(0:4)
      CALL IFILE(21,'STRA1.')
      CALL OFILE(22,'STRA2.')
1     M=1
      READ(21,5,END=500)IDATE(M),IHR(M),IMIN(M),LINE(M),ITS(M),
     2 CT(M),ION(M),IOFF(M),IC1D1(M),IC1D2(M),IC1D3(M),IC2D1(M),
     2 IC2D2(M),IC2D3(M),IC3D1(M),IC3D2(M),IC3D3(M),ICOL(M)
5     FORMAT(I8,2(I2),A2,I1,A3,2(I3),9(I1),2X,I1)

2     DO 20 M=2,4
      READ(21,5,END=23)IDATE(M),IHR(M),IMIN(M),LINE(M),ITS(M),
     2 CT(M),ION(M),IOFF(M),IC1D1(M),IC1D2(M),IC1D3(M),IC2D1(M),
     2 IC2D2(M),IC2D3(M),IC3D1(M),IC3D2(M),IC3D3(M),ICOL(M)
      K=M

      IF(((IHR(M)*60+IMIN(M))-(IHR(M-1)*60+IMIN(M-1))).GT.2)
     2 GO TO 25
      IF(LINE(M).NE.LINE(M-1))GO TO 25
      IF(CT(M).NE.CT(M-1))GO TO 25
      IF(ITS(M).NE.ITS(M-1))GO TO 25
      IF(ICOL(M).EQ.ICOL(M-1))GO TO 25
      IF(M.LT.3)GO TO 20
      IF(ICOL(M).EQ.ICOL(M-2).OR.ICOL(M).EQ.ICOL(M-3))GO TO 25
20    CONTINUE

      GO TO 24
23    IFT=1
24    IF(K.EQ.4)K=5
25    DO 30 M=1,K-1
      ICOUNT(M)=IC1D1(M)*100000000+IC1D2(M)*10000000+IC1D3(M)*1000000+
     2 IC2D1(M)*100000+IC2D2(M)*10000+IC2D3(M)*1000+IC3D1(M)*100+
     2 IC3D2(M)*10+IC3D3(M)
      IF(ICOUNT(M).EQ.ICOUNT(M-1).AND.ION(M).EQ.ION(M-1))29,26
26    IF(M.LT.3)GO TO 28
      IF(ICOUNT(M).EQ.ICOUNT(M-2).AND.ION(M).EQ.ION(M-2))29,27
27    IF(ICOUNT(M).EQ.ICOUNT(M-3).AND.ION(M).EQ.ION(M-3))29,28
29    ICOUNT(M)=0
      IC1D1(M)=0
      IC1D2(M)=0
      IC1D3(M)=0
      IC2D1(M)=0
      IC2D2(M)=0
      IC2D3(M)=0
      IC3D1(M)=0
      IC3D2(M)=0
      IC3D3(M)=0
      ION(M)=0
      IOFF(M)=0
28    ITOTAL=ITOTAL+ICOUNT(M)
      DOOR=DOOR+IC1D1(M)+IC1D2(M)+IC1D3(M)+IC2D1(M)+IC2D2(M)+
     2 IC2D3(M)+IC3D1(M)+IC3D2(M)+IC3D3(M)
      TON=TON+ION(M)
      TOFF=TOFF+IOFF(M)
30    CONTINUE

      IF(CT(1).EQ.'CCT'.AND.ITS(1).EQ.1)40,50
40    IF(ITOTAL.EQ.110000000)190,150
```

```
50      IF(CT(1).EQ.'PCT'.AND.ITS(1).EQ.2) 60,70
60      IF(ITOTAL.EQ.110110000) 190,160

70      IF(CT(1).EQ.'PCT'.AND.ITS(1).EQ.3) 80,90
80      IF(ITOTAL.EQ.110110110) 190,170

90      IF(CT(1).EQ.'LRV'.AND.ITS(1).EQ.1) 100,110
100     IF(ITOTAL.EQ.111000000) 190,180

110     IF(CT(1).EQ.'LRV'.AND.ITS(1).EQ.2) 120,500
120     IF(ITOTAL.EQ.111111000) 190,170
150     LOFF=INT(TOFF/DOOR*2+.5)
        LON=INT(TON/DOOR*2+.5)
        GO TO 300
160     LOFF=INT(TOFF/DOOR*4+.5)
        LON=INT(TON/DOOR*4+.5)
        GO TO 300
170     LOFF=INT(TOFF/DOOR*6+.5)
        LON=INT(TON/DOOR*6+.5)
        GO TO 300
180     LOFF=INT(TOFF/DOOR*3+.5)
        LON=INT(TON/DOOR*3+.5)
        GO TO 300
190     LOFF=TOFF
        LON=TON
300     K=K-1
        WRITE(22,5) IDATE(1),IHR(1),IMIN(1),LINE(1),ITS(1),CT(1),
       2 LON,LOFF,IF
        IF(IFI.EQ.1) GO TO 500
        ITOTAL=0
        DOOR=0
        TON=0
        TOFF=0
        IF(K.EQ.5) GO TO 1
        IDATE(1)=IDATE(K)
        IHR(1)=IHR(K)
        IMIN(1)=IMIN(K)
        LINE(1)=LINE(K)
        ITS(1)=ITS(K)
        CT(1)=CT(K)
        ION(1)=ION(K)
        IOFF(1)=IOFF(K)
        IC1D1(1)=IC1D1(K)
        IC1D2(1)=IC1D2(K)
        IC1D3(1)=IC1D3(K)
        IC2D1(1)=IC2D1(K)
        IC2D2(1)=IC2D2(K)
        IC2D3(1)=IC2D3(K)
        IC3D1(1)=IC3D1(K)
        IC3D2(1)=IC3D2(K)
        IC3D3(1)=IC3D3(K)
        ICOL(1)=ICOL(K)
        GO TO 2
500     END
```

PROGRAM EDIT3

Program EDIT3 is similar to EDIT2 but is used for trains opening doors on both sides.

```
      INTEGER LINE(0:4),CT(0:4)
      DIMENSION IDATE(0:4),IHR(0:4),IMIN(0:4),ITS(0:4),
     2 ION(0:4),IOFF(0:4),IC1D1L(0:4),IC1D2L(0:4),IC1D3L(0:4),
     2 IC2D1L(0:4),IC2D2L(0:4),IC2D3L(0:4),IC3D1L(0:4),IC3D2L(0:4),
     2 IC3D3L(0:4),IC1D1R(0:4),IC1D2R(0:4),IC1D3R(0:4),IC2D1R(0:4),
     2 IC2D2R(0:4),IC2D3R(0:4),IC3D1R(0:4),IC3D2R(0:4),IC3D3R(0:4),
     2 ICOL(0:4),ICOUNT(0:4)
      CALL IFILE(21,'STRA1.')
      CALL OFILE(22,'STRA2.')
1     M=1
      READ(21,5,END=500)IDATE(M),IHR(M),IMIN(M),LINE(M),ITS(M),
     2 CT(M),ION(M),IOFF(M),IC1D1L(M),IC1D2L(M),IC1D3L(M),IC2D1L(M),
     2 IC2D2L(M),IC2D3L(M),IC3D1L(M),IC3D2L(M),IC3D3L(M),IC1D1R(M),
     2 IC1D2R(M),IC1D3R(M),IC2D1R(M),IC2D2R(M),IC2D3R(M),IC3D1R(M),
     2 IC3D2R(M),IC3D3R(M),ICOL(M)
5     FORMAT(I8,2(I2),A2,I1,A3,2(I3),9(I1),9(I1),2X,I1)

2     DO 20 M=2,4
      READ(21,5,END=23)IDATE(M),IHR(M),IMIN(M),LINE(M),ITS(M),
     2 CT(M),ION(M),IOFF(M),IC1D1L(M),IC1D2L(M),IC1D3L(M),IC2D1L(M),
     2 IC2D2L(M),IC2D3L(M),IC3D1L(M),IC3D2L(M),IC3D3L(M),
     2 IC1D1R(M),IC1D2R(M),IC1D3R(M),IC2D1R(M),IC2D2R(M),IC2D3R(M),
     2 IC3D1R(M),IC3D2R(M),IC3D3R(M),ICOL(M)
      K=M

      IF(((IHR(M)*60+IMIN(M))-(IHR(M-1)*60+IMIN(M-1))).GT.2)
     2 GO TO 25
      IF(LINE(M).NE.LINE(M-1))GO TO 25
      IF(CT(M).NE.CT(M-1))GO TO 25
      IF(ITS(M).NE.ITS(M-1))GO TO 25
      IF(ICOL(M).EQ.ICOL(M-1))GO TO 25
      IF(M.LT.3)GO TO 20
      IF(ICOL(M).EQ.ICOL(M-2).OR.ICOL(M).EQ.ICOL(M-3))GO TO 25
20    CONTINUE

      GO TO 24
23    IFI=1
24    IF(K.EQ.4)K=5
25    DO 30 M=1,K-1
      ICOUNT(M)=IC1D1L(M)*10**17+IC1D2L(M)*10**16+IC1D3L(M)*10**15+
     2 IC2D1L(M)*10**14+IC2D2L(M)*10**13+IC2D3L(M)*10**12+
     2 IC3D1L(M)*10**11+IC3D2L(M)*10**10+IC3D3L(M)*10**9+IC1D1R(M)*
     2 10**8+IC1D2R(M)*10**7+IC1D3R(M)*10**6+IC2D1R(M)*10**5+
     2 IC2D2R(M)*10**4+IC2D3R(M)*10**3+IC3D1R(M)*10**2+
     2 IC3D2R(M)*10+IC3D3R(M)
      IF(ICOUNT(M).EQ.ICOUNT(M-1).AND.ION(M).EQ.ION(M-1))29,26
26    IF(M.LT.3)GO TO 28
      IF(ICOUNT(M).EQ.ICOUNT(M-2).AND.ION(M).EQ.ION(M-2))29,27
27    IF(ICOUNT(M).EQ.ICOUNT(M-3).AND.ION(M).EQ.ION(M-3))29,28
29    ICOUNT(M)=0
      IC1D1L(M)=0
      IC1D2L(M)=0
      IC1D3L(M)=0
      IC2D1L(M)=0
      IC2D2L(M)=0
      IC2D3L(M)=0
      IC3D1L(M)=0
      IC3D2L(M)=0
      IC3D3L(M)=0
      IC1D1R(M)=0
      IC1D2R(M)=0
```

```
      IC1D3R(M)=0
      IC2D1R(M)=0
      IC2D2R(M)=0
      IC2D3R(M)=0
      IC3D1R(M)=0
      IC3D2R(M)=0
      IC3D3R(M)=0
      ION(M)=0
      IOFF(M)=0
28    ITOTAL=ITOTAL+ICOUNT(M)
      DOOR=DOOR+IC1D1L(M)+IC1D2L(M)+IC1D3L(M)+IC2D1L(M)+IC2D2L(M)+
     2 IC2D3L(M)+IC3D1L(M)+IC3D2L(M)+IC3D3L(M)+IC1D1R(M)+
     2 IC1D2R(M)+IC1D3R(M)+IC2D1R(M)+IC2D2R(M)+IC2D3R(M)+
     2 IC3D1R(M)+IC3D2R(M)+IC3D3R(M)

      TON=TON+ION(M)
      TOFF=TOFF+IOFF(M)
30    CONTINUE

      IF(CT(1).EQ.'PCC'.AND.ITS(1).EQ.1)40,50
40    IF(ITOTAL.EQ.(11*10**16+11*10**7))190,150

50    IF(CT(1).EQ.'PCC'.AND.ITS(1).EQ.2)60,70
60    IF(ITOTAL.EQ.(11*10**16+11*10**13+11*10**7+11*10**4))190,150

70    IF(CT(1).EQ.'PCC'.AND.ITS(1).EQ.3)80,90
80    IF(ITOTAL.EQ.(11*10**16+11*10**13+
     2 11*10**10+11*10**7+11*10**4+110))190,170

90    IF(CT(1).EQ.'LRV'.AND.ITS(1).EQ.1)100,110
100   IF(ITOTAL.EQ.111000000)190,180
                     111*10**15+111*10**6
110   IF(CT(1).EQ.'LRV'.AND.ITS(1).EQ.2)120,500
120   IF(ITOTAL.EQ.(111111*10**11+111111*10**3))190,170
150   LOFF=INT(TOFF/DOOR*4+.5)
      LON=INT(TON/DOOR*4+.5)
      GO TO 300
160   LOFF=INT(TOFF/DOOR*8+.5)
      LON=INT(TON/DOOR*8+.5)
      GO TO 300
170   LOFF=INT(TOFF/DOOR*12+.5)
      LON=INT(TON/DOOR*12+.5)
      GO TO 300
180   LOFF=INT(TOFF/DOOR*6+.5)
      LON=INT(TON/DOOR*6+.5)
      GO TO 300
190   LOFF=TOFF
      LON=TON
300   IK=K-1
      WRITE(22,5)IDATE(1),IHR(1),IMIN(1),LINE(1),ITS(1),CT(1),
     2 LON,LOFF,IK
      IF(IFI.EQ.1)GO TO 500
      ITOTAL=0
      DOOR=0
      TON=0
      TOFF=0
      IF(K.EQ.5)GO TO 1
      IDATE(1)=IDATE(K)
      IHR(1)=IHR(K)
      IMIN(1)=IMIN(K)
      LINE(1)=LINE(K)
```

PROGRAM EDIT3 (CONT.)

```
      ITS(I)=ITS(K)
      CT(I)=CT(K)
      ION(I)=ION(K)
      IOFF(I)=IOFF(K)
      IC101L(I)=IC101L(K)
      IC102L(I)=IC102L(K)
      IC103L(I)=IC103L(K)
      IC201L(I)=IC201L(K)
      IC202L(I)=IC202L(K)
      IC203L(I)=IC203L(K)
      IC301L(I)=IC301L(K)
      IC302L(I)=IC302L(K)
      IC303L(I)=IC303L(K)
      IC101R(I)=IC101R(K)
      IC102R(I)=IC102R(K)
      IC103R(I)=IC103R(K)
      IC201R(I)=IC201R(K)
      IC202R(I)=IC202R(K)
      IC203R(I)=IC203R(K)
      IC301R(I)=IC301R(K)
      IC302R(I)=IC302R(K)
      IC303R(I)=IC303R(K)
      ICOL(I)=ICOL(K)
      GO TO 2
500   END
```

APPENDIX 6
PROGRAM SEPAR

Program SEPAR sorts the data into two inbound and outbound files.

```
OPEN FINAL.
F AIL.
INI 1 PAKLEC.
OPI START.
L1: GETREC L3.
IF HOUR LT 7 THEN L2.
GOTO L1.
L2: CHANGE HOUR HOUR+12.
GO TO L1.
L3: OPI END.
FIND LINE EQ "L" OR "GC" OR "N" OR "P".
SORT BY HOUR MIN.
PRINT ON 1 MAYDAY HOUR MIN LINE TRAINSIZE TYPEOFCAR &
PASSON PASSOFF COLLECT FMT D4 I2 I2 A2 I1 A3 I3 I3 1X I1 END.
FIND NOT LAST.
SORT BY HOUR MIN.
INIT 2 PAKRIV.
PRINT ON 2 MAYDAY HOUR MIN LINE TRAINSIZE TYPEOFCAR &
        PASSON PASSOFF COLLECT FORMAT D4 I2 I2 A2 &
        I1 A3 I3 I3 1X I1 END.
QUIT.
```

APPENDIX 7

FINAL OUTPUTS: PAKRIV AND PAKLEC

PAKRIV

Date	Time	Line	Train size	On	Off	# of Surveyor
19780522	7 0	B	2LRV	3	2	2
19780522	710	B	2LRV	14	8	2
19780522	715	H	2LRV	0	0	2
19780522	717	BC	2PCC	0	0	2
19780522	718	CC	2PCC	0	0	2
19780522	720	B	2LRV	58	11	2
19780522	722	H	1PCC	0	0	2
19780522	723	H	1PCC	0	0	2
19780522	725	BC	2PCC	0	0	2
19780522	725	B	2LRV	9	7	2
19780522	725	H	1PCC	0	0	2
19780522	726	H	1LRV	0	0	1
19780522	726	H	1PCC	0	0	1
19780522	726	H	1LRV	0	0	1
19780522	727	B	2LRV	5	7	2
19780522	728	CC	2PCC	0	0	2
19780522	733	H	1PCC	0	0	2
19780522	734	BC	2PCC	0	0	2
19780522	735	CC	2PCC	0	0	2
19780522	740	B	2LRV	142	34	4
19780522	741	CC	2LRV	0	0	4
19780522	748	H	1PCC	0	0	4
19780522	749	CC	2PCC	0	0	4
19780522	750	H	1PCC	0	0	4
19780522	751	BC	1LRV	0	0	2
19780522	751	H	1LRV	0	0	2
19780522	752	H	1PCC	0	0	1
19780522	752	H	1LRV	0	0	2
19780522	753	B	2LRV	110	24	4
19780522	753	H	1LRV	0	0	1
19780522	755	H	1PCC	0	0	2
19780522	755	CC	2LRV	0	0	2
19780522	756	CC	1LRV	0	0	1
19780522	756	CC	2LRV	0	0	1
19780522	756	H	1PCC	0	0	4
19780522	756	B	2LRV	2	1	3
19780522	757	B	2LRV	2	0	2
19780522	758	H	1PCC	0	0	2
19780522	8 0	CC	2PCC	0	0	4
19780522	8 1	B	2LRV	23	31	4
19780522	8 4	H	1PCC	0	0	4
19780522	8 5	CC	2PCC	0	0	4
19780522	8 5	BC	3PCC	0	0	4
19780522	8 6	H	2LRV	0	0	1
19780522	8 6	H	1LRV	0	0	2
19780522	8 7	H	1LRV	0	0	1
19780522	8 9	K	1LRV	0	0	4
19780522	810	H	1PCC	0	0	2
19780522	810	BC	2PCC	0	0	4
19780522	812	B	2LRV	120	21	4
19780522	813	CC	2PCC	0	0	4
19780522	814	H	1LRV	0	0	1
19780522	815	H	1PCC	0	0	2
19780522	815	CC	2PCC	0	0	1
19780522	815	H	1PCC	0	0	2
19780522	816	H	1PCC	0	0	1
19780522	816	H	1PCC	0	0	2
19780522	817	B	2LRV	31	41	4
19780522	822	H	1PCC	0	0	4
19780522	824	B	2LRV	118	35	4
19780522	826	H	1PCC	0	0	4

PAKLEC

Date	Time	Line	Train-size	On	Off	# of Surveyors
19780524	730	GO	1LRV	0	0	2
19780524	731	N	2LRV	75	36	2
19780524	735	GO	1PCC	0	0	2
19780524	738	P	1LRV	0	0	1
19780524	739	L	2PCC	130	162	2
19780524	740	GO	1PCC	0	0	1
19780524	741	GO	1LRV	0	0	2
19780524	742	N	2LRV	36	73	2
19780524	743	L	3PCC	22	49	2
19780524	744	GO	1PCC	0	0	2
19780524	748	N	2LRV	24	138	1
19780524	748	L	2LRV	80	168	2
19780524	748	GO	1PCC	0	0	2
19780524	749	GO	2PCC	0	0	1
19780524	749	GO	1PCC	0	0	1
19780524	750	L	2LRV	66	54	1
19780524	753	N	2LRV	105	213	2
19780524	755	L	3PCC	15	67	2
19780524	757	N	2LRV	15	101	2
19780524	758	GO	1PCC	0	0	2
19780524	758	N	2LRV	1	26	2
19780524	8 0	N	2LRV	57	79	3
19780524	8 4	GO	1PCC	0	0	4
19780524	8 4	L	2PCC	43	109	3
19780524	8 5	L	3PCC	15	65	4
19780524	8 5	GO	1LRV	0	0	4
19780524	8 6	L	2PCC	8	54	4
19780524	8 7	GO	1PCC	0	0	4
19780524	8 8	GO	1PCC	0	0	4
19780524	814	N	2LRV	63	109	4
19780524	815	L	3PCC	3	99	4
19780524	816	L	2PCC	45	78	4
19780524	817	GO	1PCC	0	0	3
19780524	818	L	2PCC	0	110	4
19780524	819	N	1LRV	2	90	4
19780524	820	GO	1PCC	0	0	4
19780524	824	GO	3PCC	0	0	4
19780524	826	L	3PCC	52	127	4
19780524	827	L	2PCC	1	62	4
19780524	829	GO	1PCC	0	0	4
19780524	829	N	1LRV	1	111	4
19780524	830	GO	1PCC	0	0	4
19780524	830	P	1LRV	0	0	1
19780524	830	GO	1PCC	0	0	4
19780524	832	GO	2PCC	0	0	4
19780524	835	L	2PCC	65	101	4
19780524	836	N	2LRV	2	130	4
19780524	836	GO	1PCC	0	0	4
19780524	838	L	2PCC	34	112	4
19780524	840	GO	1PCC	0	0	4
19780524	841	L	3PCC	4	95	4
19780524	842	N	1LRV	0	88	4
19780524	843	GO	1PCC	0	0	3
19780524	846	L	3PCC	24	110	4
19780524	847	P	1LRV	0	0	1
19780524	847	GO	1PCC	0	0	3
19780524	848	N	1LRV	2	46	4
19780524	850	L	2PCC	0	57	4
19780524	852	GO	1PCC	0	0	4
19780524	852	L	2PCC	17	104	4
19780524	853	GO	2PCC	0	0	3

APPENDIX 8
PROGRAM PROPFL

Program PROPFL generates the actual time series of the observed data for individual stations.

```
          INTEGER TRAIN(500)
          DIMENSION IHR(500),IMIN(500),ION(500),IOFF(500)
          DOUBLE PRECISION FILEOU, FILEIN, DIR,STAT
          TYPE 5
5         FORMAT('INPUT FILE NAME =',$)
          ACCEPT 6, FILEIN
          TYPE 4
4         FORMAT('OUTPUT FILE NAME = ',$)
          ACCEPT 6,FILEOU
6         FORMAT(A10)
          OPEN(UNIT=21,DEVICE='DSK',ACCESS='SEQIN',FILE=FILEIN)
          OPEN(UNIT=22,DEVICE='DSK',ACCESS='SEQOUT',FILE=FILEOU)
          TYPE 7
7         FORMAT('TO WHAT DIRECTION?',1X,$)
          ACCEPT 8,DIR
8         FORMAT(A10)
          TYPE 9
9         FORMAT ('AT WHAT STATION?',1X,$)
          ACCEPT 10,STAT
10        FORMAT(A10)
          WRITE(22,11)STAT,DIR
          WRITE (22,12)
12        FORMAT(//2X,'TIME',2X,'HEADWAY',2X,'PASS ON',1X,'ON RATE',
          2 1X,'PASS OFF',1X,'OFF RATE',2X,'TRAIN IN BET')
          N=0
          ITIME=0
          DO 100 I=1,500
          READ(21,20,END=500)IHR(I),IMIN(I),TRAIN(I),ION(I),
          2 IOFF(I)
20        FORMAT(8X,I2,I2,A2,4X,I3,I3,2X)
          PASSON=ION(I)
          PASOFF=IOFF(I)
          NUM=I-N-1
          IF(DIR.EQ.'LECHMERE')GO TO 23
          IF(TRAIN(I).EQ.'R ')23,100
23        HEDWAY=(IHR(I)*60+IMIN(I))-ITIME
          PEDWAY=HEDWAY
          IF(HEDWAY.EQ.0) PEDWAY=1
          RATEON=PASSON/PEDWAY
          RATOFF=PASOFF/PEDWAY
          WRITE(22,50)IHR(I),IMIN(I),HEDWAY,ION(I),RATEON,IOFF(I),
          2 RATOFF,NUM
11        FORMAT(1X,'AT STATION=',1X,A10,'GOING TO',1X,A10)
50        FORMAT(2X,I2,I2,4X,F5.1,5X,I3,5X,F4.1,
          25X,I3,5X,F4.1,8X,I2)
60        ITIME=IHR(I)*60+IMIN(I)
          N=I
100       CONTINUE
500       END
```

APPENDIX 9
STATION PROFILE: PAKPFL

AT STATION = PARK ST. GOING TO RIVERSIDE

TIME	HEADWAY	PASS ON	ON RATE	PASS OFF	OFF RATE	TRAIN IN BET
7 0	420.0*	3	0.0	2	0.0	0
710	10.0	14	1.4	8	0.8	0
720	10.0	58	5.8	11	1.1	3
725	5.0	9	1.8	7	1.4	3
727	2.0	6	3.0	7	3.5	4
740	13.0	142	10.9	34	2.6	4
753	13.0	110	8.5	24	1.8	8
756	3.0	2	0.7	1	0.3	6
757	1.0	2	2.0	0	0.0	0
8 1	4.0	33	8.3	31	7.8	2
812	11.0	120	10.9	21	1.9	9
817	5.0	91	18.2	41	8.2	7
824	7.0	118	16.9	35	5.0	1
840	16.0	94	5.9	30	1.9	7
847	7.0	47	6.7	42	6.0	9
848	1.0	33	33.0	21	21.0	0
854	6.0	16	2.7	3	0.5	4
9 0	15.0	54	3.6	11	0.7	20
911	2.0	25	12.5	2	1.0	3
915	4.0	39	9.8	8	2.0	1
928	13.0	24	1.8	39	3.0	9
934	6.0	38	6.3	23	3.8	5
940	6.0	21	3.5	6	1.0	5
950	10.0	22	2.2	57	5.7	7
956	6.0	17	2.8	5	0.8	7
1012	16.0	39	2.4	10	0.6	7
1024	12.0	74	6.2	0	0.0	3
1025	1.0	12	12.0	9	9.0	2
1026	1.0	12	12.0	14	14.0	0
1334	188.0*	72	0.4	12	0.1	5
1342	8.0	20	2.5	15	1.9	4
1355	13.0	[illegible]	5.9	39	3.0	2
1359	4.0	21	5.3	33	8.3	2
14 5	6.0	15	2.5	18	3.0	4
1412	7.0	72	10.3	24	3.4	1
1423	11.0	24	2.2	6	0.5	8
1428	5.0	21	4.2	18	3.6	6
1441	13.0	102	7.8	21	1.6	7
1448	7.0	25	3.6	4	0.6	4
1459	11.0	87	7.9	33	3.0	6
15 3	4.0	29	7.3	7	1.8	3
1512	9.0	117	13.0	78	8.7	12
1523	11.0	92	8.4	68	6.2	11
1526	3.0	95	31.7	36	12.0	2
1532	6.0	11	1.8	30	5.0	4
1534	2.0	14	7.0	4	2.0	3
1537	3.0	16	5.3	14	4.7	2
1549	12.0	62	5.2	17	1.4	5
1555	6.0	45	7.5	33	5.5	6
16 5	10.0	50	5.0	15	1.5	6
1615	10.0	59	5.9	29	2.9	8
1618	3.0	48	16.0	57	19.0	0
1627	9.0	60	6.7	29	3.2	8
1630	3.0	32	10.7	21	7.0	3
1641	11.0	221	20.1	186	16.9	3
1652	11.0	102	9.3	19	1.7	10
1655	3.0	66	22.0	14	4.7	3

* large headways indicate break in data

1711	15.0	111	5.9	0	0.0	6
1718	7.0	112	15.1	51	7.3	4
1721	3.0	138	52.7	92	30.7	2
1726	5.0	66	13.2	17	3.4	5
1730	4.0	26	5.5	16	4.0	3
1730	0.0	29	22.0	12	12.0	0
1731	1.0	41	41.0	29	29.0	0
1733	2.0	22	11.0	40	20.0	3
1742	9.0	87	9.7	9	1.0	6
1744	2.0	9	4.5	4	2.0	2
1800	15.0	113	7.4	38	2.4	12
1806	6.0	32	5.3	48	8.0	2
1808	2.0	30	15.0	2	1.0	3
1810	2.0	46	23.0	7	3.5	0

AT STATION = PK ST. GOING TO NORTH STATION

TIME	HEADWAY	PASS ON	ON RATE	PASS OFF	OFF RATE	# IN IN BET
731	451.0	75	0.2	36	0.1	1
742	11.0	25	2.3	78	7.1	5
748	6.0	24	4.0	138	23.0	2
753	5.0	106	21.2	218	43.6	5
757	4.0	15	3.8	101	25.3	1
758	1.0	1	1.0	26	26.0	1
8 0	2.0	53	26.5	79	39.5	0
814	14.0	63	4.5	109	7.8	7
819	5.0	2	0.4	90	18.0	4
829	10.0	1	0.1	111	11.1	5
836	7.0	2	0.3	130	18.6	5
842	6.0	0	0.0	88	14.7	4
848	6.0	3	0.5	46	7.7	4
856	8.0	12	1.5	89	11.1	7
919	23.0	1	0.0	26	1.1	14
922	3.0	7	2.3	46	15.3	5
928	6.0	13	2.2	75	12.5	6
930	2.0	6	3.0	42	21.0	2
940	10.0	0	0.0	59	5.9	8
949	9.0	6	0.7	42	4.7	7
954	5.0	16	3.2	70	14.0	2
959	5.0	13	2.6	80	16.0	2
10 9	10.0	0	0.0	38	3.8	5
1014	5.0	11	2.2	46	9.2	3
1027	13.0	17	1.3	59	4.5	6
1039	12.0	8	0.7	59	4.9	5
1051	12.0	9	0.8	115	9.6	3
1058	7.0	8	1.1	49	7.0	3
1524	266.0	324	1.2	312	1.2	4
1530	6.0	30	5.0	62	10.3	2
1543	13.0	34	2.6	46	3.5	11
1544	1.0	6	6.0	79	79.0	0
1550	6.0	14	2.3	93	15.5	4
16 0	10.0	0	0.0	27	2.7	10
1610	10.0	92	9.2	206	20.6	1
1618	8.0	39	4.9	39	4.9	4
1621	3.0	22	7.3	74	24.7	3
1627	6.0	14	2.3	119	19.8	7
1634	7.0	19	2.7	132	18.9	6
1637	3.0	11	3.7	53	17.7	2
1648	11.0	8	0.7	52	4.7	4
17 0	12.0	34	2.8	103	8.6	7
1713	13.0	34	6.5	132	10.2	10
1719	6.0	40	6.7	104	17.3	3
1725	6.0	17	2.8	61	10.2	4
1727	2.0	13	6.5	36	19.0	1
1743	16.0	5	0.3	74	4.6	11
1744	1.0	12	12.0	58	58.0	0
18 9	25.0	4	0.2	62	2.5	11
1828	19.0	45	2.4	99	5.2	9

*Large headways indicate breaks in data.

APPENDIX 10
PROGRAM CONTRAC

Program CONTRAC contracts PAKPFL into half-hour intervals.

```
         DIMENSION ITIME(100),INT(100),ION(100),IOFF(100),
         2 TON(50),TOFF(50),TOHWY(50),HEDWAY(100),
         2 RAON(50),RAOFF(50).
         DOUBLE PRECISION FILEOU, FILEIN
         TYPE 5
5        FORMAT('INPUT FILE NAME = ',$)
         ACCEPT 6, FILEIN
6        FORMAT(A10)
         TYPE 7
7        FORMAT('OUTPUT FILE NAME = ',$)
         ACCEPT 6, FILEOU
         OPEN(UNIT=21,DEVICE='DSK',ACCESS='SEQIN',FILE=FILEIN)
         OPEN(UNIT=22,DEVICE='DSK',ACCESS='SEQOUT',FILE=FILEOU)
         DATA(INT(K),K=1,28)/700,730,800,830,900,930,1000,1030,
         2 1100,1130,1200,1230,1300,1330,1400,1430,1500,1530,
         2 1600,1630,1700,1730,1800,1830,1900,1930,2000,2030/
         K=1
10       FORMAT(////,2X,I4,4X,F5.1,5X,I3,14X,I3,19X)
11       DO 25 I=1,100
         IF(I.EQ.1)13,14
13       READ(21,10)ITIME(I),HEDWAY(I),ION(I),IOFF(I)
         GO TO 15
14       READ(21,12,END=20)ITIME(I),HEDWAY(I), ION(I), IOFF(I)
12       FORMAT(2X,I4,4X,F5.1,5X,I3,14X,I3,19X)
15       IF(ITIME(I).LE.INT(K))16,21
16       IF(HEDWAY(I).GT.30.0)25,18
18       TOHWY(K)=TOHWY(K)+HEDWAY(I)
         TON(K)=TON(K)+ION(I)
         TOFF(K)=TOFF(K)+IOFF(I)
         GO TO 25
20       M=1
21       IF(TOHWY(K).EQ.0)TOHWY(K)=1.0
         RAON(K)=TON(K)/TOHWY(K)
         RAOFF(K)=TOFF(K)/TOHWY(K)
         WRITE(22,24)INT(K),RAON(K),RAOFF(K)
24       FORMAT(I4,1X,F6.2,1X,F6.2)
         IF(M.EQ.1)GO TO 30
         K=K+1
         GO TO 15
25       CONTINUE
30       END
```

APPENDIX 11
PROGRAM COMBIN

Program COMBIN combines all station data into an input matrix.

```
      DIMENSION RAON(20,28),RAOFF(20,28),INT(50)
      DOUBLE PRECISION FILEIN
      OPEN(UNIT=23,DEVICE='DSK',ACCESS='SEQOUT',FILE='PASOUT.')
      OPEN(UNIT=22,DEVICE='DSK',ACCESS='SEQOUT',FILE='PASSIN.')
      DATA(INT(K),K=1,26)/700,730,800,830,900,930,1000,1030,
     2 1100,1130,1200,1230,1300,1330,1400,1430,1500,1530,
     2 1600,1630,1700,1730,1800,1830,1900/
      WRITE(5,1)
1     FORMAT('NUMBER OF STATIONS=', $)
      ACCEPT 2, MS
2     FORMAT(I2)
      DO 50 I=1,MS
      TYPE 6
6     FORMAT('INPUT FILE = ',$)
      ACCEPT 7, FILEIN
7     FORMAT(A10)
      OPEN(UNIT=21,DEVICE='DSK',ACCESS='SEQIN',FILE=FILEIN)
      DO 25 J=1,26
      READ(21,10,END=12)RAON(I,J),RAOFF(I,J)
10    FORMAT(5X,F6.2,1X,F6.2)
      GO TO 25
12    RAON(I,J)=0
      RAOFF(I,J)=0
25    CONTINUE
      CLOSE(UNIT=21)
50    CONTINUE
      DO 60 J=1,26
      WRITE(22,52)INT(J),(RAON(I,J),I=1,MS)
52    FORMAT(I4,1X,26(F6.2))
60    CONTINUE
      DO 70 J=1,26
      WRITE(23,52)INT(J),(RAOFF(I,J),I=1,MS)
70    CONTINUE
      END
```

APPENDIX 12
PROGRAM ESTREG

Program ESTREG estimates the missing values by regression.

```
      DOUBLE PRECISION FILEIN,FILEOU
      DIMENSION XBAR(35),STD(35),D(35),RY(35),ISAVE(35),B(35),
     2 SB(35),T(35),W(35),RX(1500),R(1000),ANS(10),RATE(25,11),
     2 PRATE(275),RES(275),OPATE(275),ERATE(275),Y(35,275),
     2 Y2(35,275),TVAR(25,275),SVAR(11,275),P(35),X1(10000)
     2 ,INT(25),TVAR1(25,275),SVAR1(11,275),B1(35),WK(35)
     2 , AL(275), BE(275),STRES(275)

      WRITE(5,1000)
1000  FORMAT('INPUT FILE = ',$)
      ACCEPT 2000, FILEIN
2000  FORMAT(A10)
      WRITE(5,3000)
3000  FORMAT('OUTPUT FILE=',$)
      ACCEPT 2000, FILEOU
      WRITE(5,4000)
4000  FORMAT('NUMBER OF STATIONS= ',$)
      ACCEPT 5000, MS
5000  FORMAT(I2)
      WRITE(5,6000)
6000  FORMAT('NUMBER OF TIME PERIODS= ',$)
      ACCEPT 5000, MT

      MK=MT+MS-1
      ML=MK-1
      MC=MT*MS

      OPEN(UNIT=21,DEVICE='DSK',ACCESS='SEQIN',FILE=FILEIN)
      OPEN(UNIT=22,DEVICE='DSK',ACCESS='SEQOUT',FILE=FILEOU)

      DO 5 I=1,MT
      READ(21,4)INT(I),(RATE(I,J),J=1,MS)
4     FORMAT(I4,1X,11(F6.2))
5     CONTINUE

C     ESTABLISH INDEPENDENT VARIABLES Y
      M=0
      DO 12 I=1,MT
      DO 10 J=1,MS
      IF(RATE(I,J).EQ.0)GO TO 10
      M=M+1
      TVAR(I,M)=1
      SVAR(J,M)=1
      PRATE(M)=ALOG(RATE(I,J))
10    CONTINUE
12    CONTINUE

      DO 20 L=1,M
      Y(1,L)=PRATE(I)
      DO 13 I=1,MT-1
      Y(I+1,L)=TVAR(I,L)
13    CONTINUE
      IF(TVAR(MT,L).NE.1)GO TO 15
      DO 14 I=1,MT-1
      Y(I+1,L)=-1
14    CONTINUE
15    DO 16 J=1,MS-1
      Y(MT+J,L)=SVAR(J,L)
16    CONTINUE
```

```
      IF(SVAR(MS,L).NE.1)GO TO 20
      DO 17 J=1,MS-1
      Y(MT+J,L)=-1
17    CONTINUE
20    CONTINUE

C     CONVERT Y TO DESIRED FORMAT OF REG. SUBROUTINE
      K=0
      DO 135 I=1,MK
      DO 134 J=1,M
      K=K+1
      X1(K)=Y(I,J)
134   CONTINUE
135   CONTINUE

C     OBTAIN CORELATION MATRIX
      CALL CORRE(M,MK,1,X1,XBAR,STD,RX,R,B1,D,T)

C     IDENTIFY INDEPENDENT VARIABLE VECTOR ISAVE
      DO 165 L=1,ML
      ISAVE(L)=L+1
165   CONTINUE

      CALL ORDER(MK,R,1,ML,ISAVE,RX,RY)
      CALL MINV(RX,ML,DET,WK,T)
      CALL MULTR(M,ML,XBAR,STD,B1,RX,RY,ISAVE,B,SB,T,ANS)

      WRITE(22,250)
250   FORMAT(18X,39HANALYSIS OF VARIANCE FOR THE REGRESSION//)
      WRITE(22,252)
252   FORMAT(2X,19HSOURCE OF VARIATION,9X,2HDF,2X,13HSUM OF SQUARE
     2,3X,11HMEAN SQUARE,6X,7HF-VALUE)
      WRITE(22,260)ANS(5),ANS(4),ANS(6),ANS(10)
260   FORMAT(2X,26HATTRIBUTABLE TO REGRESSION,2X,F3.0,3X,
     2F10.4,5X,F10.4,3X,F10.4)
      WRITE(22,265)ANS(8),ANS(7),ANS(9)
265   FORMAT(2X,25HDEVIATION FROM REGRESSION,3X,F3.0,3X,F10.4,5X,
     2F10.4,3X,F10.4)
      WRITE(22,270)ANS(1)
270   FORMAT(//1X,10HINTERCEPT=F9.3)
      ANS(2)=ANS(2)**2
      WRITE(22,275)ANS(2)
275   FORMAT(1X,29HMULTIPLE CORR. COEFF. SQUARE=F6.5)
      WRITE(22,280)ANS(3)
280   FORMAT(1X,27HSTANDARD ERROR OF ESTIMATE=F9.3//)
      WRITE(22,290)
290   FORMAT(2X,8HVARIABLE,10X,12HREGR. COEFF.,10X,10HSTD.
     2ERROR,10X,8HCOMPUTED)
      WRITE(22,295)
295   FORMAT(43X,9HOF COEFF.,11X,7HT-VALUE//)
      DO 310 J=1,ML
      WRITE(22,300)ISAVE(J),B(J),SB(J),T(J)
300   FORMAT(6X,I2,14X,F10.4,11X,F9.4,10X,F9.4)
310   CONTINUE
      DO 313 L=1,M
      ALSQ=0
      BESQ=0
      ALSQ1=0
      BESQ1=0
      DO 311 K6=2,MT
      AL(L)=AL(L)+Y(K6,L)*B(K6-1)
```

```
      ALSQ=ALSQ+B(K6-1)**2
      ALSQ1=ALSQ1+B(K6-1)
311   CONTINUE
      DO 312 K7=MT+1,MK
      BE(L)=BE(L)+Y(K7,L)*B(K7-1)
      BESQ=BESQ+B(K7-1)**2
      BESQ1=BESQ1+B(K7-1)
312   CONTINUE
      DS=DS+Y(1,L)*AL(L)*BE(L)
313   CONTINUE
      ALSQ=ALSQ+ALSQ1**2
      BESQ=BESQ+BESQ1**2
      DSTAT=(DS**2)/(ALSQ*BESQ)
      SSPE=ANS(7)-DSTAT
      FSTAT=DSTAT*(ANS(8)-1)/SSPE
      WRITE(22,314)FSTAT
314   FORMAT(//'THE INTERACTION TEST STAT. , FSTAT:',1X,F10.4)

C     OBTAIN ESTIMATES FOR MISSING VALUES AND RESIDUALS
      KL=0
      DO 320 I=1,MT
      DO 315 J=1,MS
      KL=KL+1
      TVAR1(I,KL)=1
      SVAR1(J,KL)=1
      ORATE(KL)=RATE(I,J)
315   CONTINUE
320   CONTINUE
      DO 330 L1=1,MC
      DO 325 I=1,MT-1
      Y2(I,L1)=TVAR1(I,L1)
325   CONTINUE
      IF(TVAR1(MT,L1).NE.1)GO TO 327
      DO 326 I=1,MT-1
      Y2(I,L1)=-1
326   CONTINUE
327   DO 328 J=1,MS-1
      Y2(MT-1+J,L1)=SVAR1(J,L1)
328   CONTINUE
      IF(SVAR1(MS,L1).NE.1)GO TO 330
      DO 329 J=1,MS-1
      Y2(MT-1+J,L1)=-1
329   CONTINUE
330   CONTINUE

      DO 340 L2=1,MC
      T1=0
      DO 335 K3=1,ML
      T1=T1+B(K3)*Y2(K3,L2)
335   CONTINUE
      ERATE(L2)=ANS(1)+T1
      IF(ORATE(L2).NE.0)RES(L2)=ALOG(ORATE(L2))-ERATE(L2)
      STRES(L2)=RES(L2)/SQRT(ANS(9))
      ERATE(L2)=EXP(ERATE(L2))
340   CONTINUE

      WRITE(22,350)
350   FORMAT(//,'ORIG.RATE',1X,'FITTED RATE',1X,'RESIDUAL',
     2 1X, 'STAND.RES.')
      DO 352 L2=1,MC
      WRITE(22,351)ORATE(L2),ERATE(L2),RES(L2),STRES(L2)
```

```
351     FORMAT(2X,F6.2,4X,F6.2,4X,F6.2,5X,F6.2)
352     CONTINUE
        DO 353 L2=1,MC
        IF(ORATE(L2).NE.0) ERATE(L2)=ORATE(L2)
353     CONTINUE
        I=1
        L2=1
        WRITE(22,356)
356     FORMAT(///,'ESTIMATED UNLOADING RATE - ALL RIVERSIDE TRAINS',//,
        2 'TIME',2X,'KENMORE',1X,'AUDIT.',2X,'COPLEY',2X,'ARLING',
        2 2X,'BOYLST.',1X,'PK.ST.',2X,'GOV.CTR',1X,'HAYMKT',2X,
        2 'NOR.STA',1X,'SC.PK.',2X,'LECHMERE')
354     WRITE(22,355)INT(I),(ERATE(L2+J),J=0,MS-1)
        L2=L2+MS
        I=I+1
        IF(L2.LE.MC)GO TO 354
355     FORMAT(I4,2X,11(F6.2,2X))
400     END
        SUBROUTINE DATA
        RETURN
        END
```

APPENDIX 13
ANOVA RESULTS

RIVOFF.MTY; Model (3) analysis of variance for the regression (Transformed data)

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F-VALUE
ATTRIBUTABLE TO REGRESSION	31.	146.3501	4.7210	10.0632
DEVIATION FROM REGRESSION	65.	30.4937	0.4691	

INTERCEPT= 0.041
MULTIPLE CORR. COEFF. SQUARE=.82757
STANDARD ERROR OF ESTIMATE= 0.685

VARIABLE	REGR. COEFF.	STD.ERROR, OF COEFF.	COMPUTED T-VALUE
2	0.0421	0.7105	0.0593
3	-0.5474	0.4024	-1.3602
4	0.4067	0.2829	1.4374
5	0.6812	0.2829	2.4078
6	0.4350	0.3115	1.3966
7	-0.2319	0.3465	-0.6693
8	0.4156	0.3154	1.3177
9	-0.1246	0.2897	-0.4302
10	-0.9837	0.3577	-2.7498
11	-0.3746	0.3577	-1.0471
12	-0.2753	0.4150	-0.6633
13	-0.6597	0.4010	-1.6452
14	-0.3688	0.7105	-0.5191
15	-0.3714	0.4881	-0.7609
16	0.2183	0.3097	0.7049
17	-0.1597	0.3097	-0.5155
18	-0.2602	0.3472	-0.7493
19	0.3940	0.3472	1.1347
20	0.5742	0.3456	1.6613
21	0.7678	0.3456	2.2213
22	0.7146	0.3113	2.2955
23	0.4602	0.3456	1.3313
24	0.9076	0.3113	2.9152
25	0.2987	0.3965	0.7533
26	0.8251	0.1534	5.3781
27	0.0963	0.3139	0.3067
28	1.4366	0.2711	5.2982
29	0.9529	0.2303	4.1369
30	-0.7833	0.1937	-4.0432
31	0.8289	0.1720	4.8184
32	-0.7414	0.2025	-3.6609

THE INTERACTION TEST STAT. , FSTAT: 10.0026

NORON.MTY; Model (3) analysis of variance for the regression (Transformed data)

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F-VALUE
ATTRIBUTABLE TO REGRESSION	30.	111.1235	3.7041	5.8990
DEVIATION FROM REGRESSION	66.	41.4427	0.6279	

INTERCEPT= -0.375
MULTIPLE CORR. COEFF. SQUARE=.72836
STANDARD ERROR OF ESTIMATE= 0.792

VARIABLE	REGR. COEFF.	STD.ERROR, OF COEFF.	COMPUTED T-VALUE
2	-1.7435	0.8023	-2.1733
3	-1.3899	0.8023	-1.7325
4	0.3695	0.4577	0.8074
5	0.2950	0.3573	0.8256
6	0.4035	0.4034	1.0003
7	-0.2205	0.3640	-0.6057
8	-0.4674	0.3681	-1.2699
9	-0.3418	0.3152	-1.0843
10	0.0007	0.3092	0.0023
11	-0.3389	0.3331	-1.0175
12	-0.7660	0.3984	-1.9228
13	-0.4118	0.4562	-0.9026
14	-0.4933	0.7843	-0.6289
15	-0.0676	0.4630	-0.1460
16	-0.0327	0.4630	-0.0707
17	-0.0525	0.4630	-0.1134
18	0.4997	0.8023	0.6229
19	1.3250	0.7955	1.6655
20	0.6679	0.4604	1.4508
21	0.8779	0.3381	2.5966
22	0.9597	0.3152	3.0446
23	1.1004	0.3152	3.4911
24	-0.0027	0.3387	-0.0081
25	0.9726	0.1869	5.2039
26	0.6689	0.2695	2.4819
27	1.0098	0.2749	3.6734
28	0.4497	0.2338	1.9238
29	-1.0271	0.2553	-4.0236
30	0.6594	0.2184	3.0192
31	-0.9677	0.1979	-4.8885

THE INTERACTION TEST STAT. , FSTAT: 2.3866

ANOVA RESULTS (CONT.)

NOROFF.MTY; Model (3) analysis of variance for the regression (Transformed data)

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F-VALUE
ATTRIBUTABLE TO REGRESSION	31.	117.3748	3.7863	9.8920
DEVIATION FROM REGRESSION	76.	29.0901	0.3828	

INTERCEPT= 0.505
MULTIPLE CORR. COEFF. SQUARE=.80139
STANDARD ERROR OF ESTIMATE= 0.619

VARIABLE	REGR. COEFF.	STD.ERROR, OF COEFF.	COMPUTED T-VALUE
2	-0.9219	0.6248	-1.4756
3	-0.2182	0.6248	-0.3493
4	1.0731	0.3116	3.4433
5	0.4788	0.2555	1.8745
6	0.6644	0.2818	2.3573
7	-0.1813	0.2578	-0.7034
8	0.0581	0.2611	0.2226
9	-0.1435	0.2432	-0.5901
10	-0.1912	0.2251	-0.8492
11	-0.5318	0.2843	-1.8705
12	-0.2032	0.3106	-0.6543
13	0.1756	0.3560	0.4931
14	0.1775	0.4449	0.3990
15	-0.4322	0.3134	-1.3789
16	0.3830	0.3134	1.2219
17	0.1668	0.3134	0.5322
18	0.1217	0.4408	0.2760
19	0.2178	0.6198	0.3514
20	-0.1526	0.3583	-0.4260
21	0.0275	0.2611	0.1053
22	-0.0830	0.2432	-0.3412
23	0.0772	0.2432	0.3172
24	-0.1637	0.2432	-0.6732
25	-1.2278	0.1476	-8.3207
26	-0.3277	0.2146	-1.5274
27	-0.3381	0.2045	-1.6531
28	-0.1479	0.1837	-0.8050
29	-0.9634	0.2033	-4.7392
30	1.6122	0.1704	9.4595
31	1.1294	0.1549	7.2908
32	0.2395	0.1785	1.3416

THE INTERACTION TEST STAT. , FSTAT: 16.3779

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